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ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Professor John Milne, D.Sc., F.R.S., F.G.S., Hon. Fellow of King's College, London.

(WITH A PORTRAIT, PLATE XVII.)

IT falls to the lot of only a very few able men to take up some neglected branch of science, and by their genius, their energetic work, the discoveries they make, assisted by their personal charm and bonhomie, to be able to attract general attention to their researches, and so attain a great public success, filling with interest and enthusiasm the intelligent, and attracting even the veriest tyro within the circle of their investigation. Such has been the outcome of the life-work of our friend and associate of many years, Professor John Milne, whose untiring energy in the study of Seismology has obtained for it now a foremost place in the physical sciences as having most important bearings on the economy of the globe and the very existence of our race.

A Doctor of Science of Oxford University, an Honorary Fellow of King's College, London, Professor of Mining and Geology in the Imperial College, Japan (1875–95), and of Seismology in the University of Tokyo; decorated with the Order of the Rising Sun in 1895 by the Emperor of Japan; elected an F.G.S. in 1873; a Fellow of the Royal Society (1887); awarded the Lyell Medal by the Geological Society in 1894, and a Royal Medal by the Royal Society in 1908—Professor John Milne needs no introduction to our readers in order to commend him to a place in this Magazine among "Eminent Living Geologists".

Born at Liverpool, December 30, 1850, he was the only son of his father, John Milne, of Milnrow, and his mother, Emma Twycross, daughter of James Twycross, of Wokingham. John Milne (the son) was educated at a school in Rochdale, and at the Collegiate College, Liverpool; thence he was entered at King's College, London, and afterwards at the Royal School of Mines, Jermyn Street. After studying practical mining engineering in Cornwall and Lancashire, he spent a short time at the Bergakademie Freiberg, and thence visited the principal mining districts in Central Europe. On his return to England he was selected by Mr. Cyrus Field, Sir James Anderson, and others to report on the mineral resources of Newfoundland and Labrador, where he spent two years (Geol. Mag., 1874, pp. 76–7). Thence he visited Funk Island, a small barren rock

now swept by the high tides of the Atlantic, but once the home of the Great Auk, and obtained a large collection of skeletons of this now extinct flightless bird, formerly so abundant around the coasts of all the northern lands, including our own Islands.

When only a schoolboy Milne paid a visit, without parental leave, in his holidays to Iceland, about the volcanic geology of which he early became interested by a school prize he had received.

In 1874 John Milne joined the expedition of Dr. Beke, which, under the auspices of the Royal Geographical Society and the Rothschilds, was sent out to fix the exact site of Mount Sinai. During this exploration he visited Cairo and made some interesting geological notes on its environs (printed in this Magazine for 1874, p. 353).

In 1875 Mr. Milne was appointed consulting engineer to the newly-formed Public Works Department of the Japanese Government, and it is characteristic of the man that, instead of going comfortably to his post by the P. and O. mail packet, he started from Hull on August 3, 1875, and made his way alone across Europe and Asia, following to some extent the line of the present Siberian Railway, then unheard of, and did not emerge at Shanghai until nearly a twelvemonth later. He landed at Göttenborg, crossed Norway, Sweden, and part of Finland, and so to St. Petersburg. It took Milne eleven months, following the old trade routes, and but few would care to endure the dangers and discomforts of travelling thus through Siberia, Central Asia, and China. His way led him across Russia and the Urals into Siberia, thence by camel through Mongolia until he reached "the Great Wall of China" on January 11, 1876. On one section of the route, for thirty-one days there were no roads, no houses, no bread, no vegetables, no washing, no change of dress day or night, plenty of snow, and from 40 to 50 degrees of frost.

For many days in the heart of China (where he was styled a "foreign devil" by the natives) he was carried in a palankeen attached to a couple of mules. It was not until February 24 that he reached Shanghai.

Professor Milne's experience of earthquakes began the first night he spent in Tokyo, where he was attached to the Department of Mines and Public Works. His residence provided for him by the Government was named 'Yama Gouchi', or the Mouth of the Mountain. It proved a fitting introduction to the country. During the night for a few minutes the dwelling creaked and groaned and rolled from side to side, pictures see-sawed on the walls, while the rings attached to the mosquito-curtains jingled in a high treble. His career as a seismologist may be said to have dated from that moment, and he has grappled with the intricacies of the subject ever since. How could one fail to become interested in earthquakes, where, as Professor Milne says, "one had earthquakes for breakfast, for dinner, and for supper, and to sleep on." He soon began to make progress in his study of the new science, and also to perceive the imperative need for widespread co-operation.

With the fresh enthusiasm engendered by the disastrous earthquake of February 22, 1880, when Yokohama bore the appearance of a town that had been bombarded, he issued a call for a public meeting, which

met with a hearty response. General van Buren presided, and the large hall was crowded with several hundred Japanese and foreigners. The world's first seismological society was formed that evening—the Seismological Society of Japan—and it has done the pioneer work, as well as having been the most active and useful. It at once enrolled about 300 members, with Mr. J. Hattori as president and Professor Milne as honorary secretary. For fifteen years Milne held that office, and directed the Society's work; the results are shown in its twenty volumes of reports, now known to seismologists all the world over, containing as they do the groundwork of the subject.

The Japanese Government soon saw the wisdom of encouraging the new science, and it established an Earthquake Committee, which it still supports with an annual subsidy on an average of $10,000 per annum, reaching in some years as high as $25,000. Wherever there is a considerable earthquake, there by the first boat goes a seismologist, an engineer, and an architect, and every phase of the disturbance and its after-effect is carefully studied and a report prepared. At the present day there are 968 stations scattered all over the Japanese Empire where these movements are recorded, a special bureau to which the reports are sent and analysed, and a chair of Seismology established at the Imperial University. The first to be appointed was Professor Milne, who occupied the chair of Seismology until he left for England in 1895.

The greatest earthquake which occurred during Professor Milne's residence in Japan (1876–95) was that of 1891. "It occurred," says Milne, "at six in the morning. I got into the open in time to see the next house tumbling to pieces. This was in the capital, where the Imperial Hotel was ruined, and the University buildings considerably damaged; but the worst effects were further south. Nine thousand nine hundred and sixty-eight persons lost their lives, and the number injured exceeded a hundred thousand. Railways and bridges were destroyed, 400 miles of river and canal embankments smashed, and the sides of mountains fell out and formed lakes by damming up the rivers. The Government spent thirty millions of dollars in relief works and repairing damages; and as the earthquake just lasted 30 seconds, it may be said to have cost the Government alone a million a second."

Fewer large earthquakes have occurred since 1891—one at Tokyo (1894) cost twenty-six lives, and another in the northern provinces killed about three hundred people. That at Kamaishi in 1896, which caused a loss of thirty thousand lives, is said to have been due to enormous tidal waves which swept the coast. These waves are not uncommon off Japan. In 1855 one partially destroyed the town of Shimoda, where Perry landed and got his treaty; and in 1868 and again in 1877 such seaquake waves were felt along the coast of Japan from north to south, rising and falling at short intervals like an ordinary tide, only vastly bigger; they were due to earthquakes in South America. Disasters like that at Kamaishi probably owe their origin to disturbances close to the coast, and therefore the waves rushed in with greater violence. They may have been caused either by a submarine eruption or a gigantic landslip at the bottom of the

ocean. The origin of the large earthquakes for many years past, felt along the eastern coast of Japan, has been traced to a point perhaps a hundred miles out to sea, and such a line lies on the synclinal folding which forms the sub-Pacific trough of the northern island. It is quite probable that this 'folding' is still in progress, and from time to time the crumpling crust reaches the limits of elasticity and suddenly breaks. This is probably the reason for 95 per cent of these disturbances. For the remainder volcanic explosions may account. And when it is considered that there are about a hundred volcanoes in Japan that have been active during the historic period, that is not a large proportion of terrestrial disturbances to lay to their charge.

In addition to the accumulated scientific knowledge which has resulted from these researches, the Government of Japan has derived no small economic advantage from Professor Milne's careful studies in seismology. The method of building bridges and houses has been entirely revolutionized. For example, the piers of bridges are now made thicker at their bases and taper upwards, instead of being built with straight sides as in Europe, and brick factory-chimneys have been replaced by structures of sheet-iron. A severe earthquake now would not cause one-fourth of the damage which would have been inevitable a few years ago.

Holidays that came at long intervals in Professor Milne's strenuous work at Tokyo were spent in the exploration of earthquake areas on the Pacific seaboard, from the Kuriles and Corea to Manila, Borneo, the Australian Colonies, and many volcanic islands. He also visited the United States. Professor Milne spent two decades in Japan, and on returning to England in 1895 he left behind him a well-trained staff in the Department of Seismology, and many well-equipped and actively-working observation-stations throughout the country.

His attachment to Japan was sealed by his marriage to Miss Tone Noritsune, and before he left for home the Mikado conferred upon him the Japanese Order of the Rising Sun and a pension as a token of His Majesty's appreciation of the value of Professor Milne's services in the cause of science during his long residence in Japan.

He soon settled at Shide, near Newport, not far from the centre of the Isle of Wight. Here he has been indefatigable; experimenting, comparing, writing. Most of the writing, like that done during his years in Japan, has gone into the transactions and reports of learned societies. *Earthquakes* (1883) and *Seismology* (1898) are his only works in book-form, although he has also published a *Miner's Handbook* and a book on Crystallography. This year he published a *Catalogue of Destructive Earthquakes, A.D. 7 to A.D. 1899*, contributed to the British Association Portsmouth Meeting, 1911 (issued as an octavo pamphlet, pp. 92); a most arduous and valuable piece of bibliographical research in Seismology.

"It would be extremely interesting to see all Milne's contributions brought together and methodically arranged. Only then could we fully grasp how great is the debt of the world to him.

"Early in his researches Professor Milne conceived the idea of his first seismograph for measuring the amplitude and period of earth

vibrations. From noticing the long distances to which the movements of a violent shock reached, his attention was drawn to the fact that, simultaneously with a great shock, in far parts of the world where this could not be felt, other phenomena were noticed, such as the movement of water, the deflection of scientific instruments, etc. This led him to write in 1883, in his book on *Earthquakes*, 'it is not unlikely that every large earthquake might, with proper instrumental appliances, be recorded at any point on the land-surface of our globe.' He now knows this to be a fact, and from the proof of this surmise dates the progress of the new seismology."[1]

"After finding that the instrument recorded an earthquake somewhere, came the discovery that every earthquake gave rise to different types of waves which travelled on different paths. There are waves which proceed straight through the earth, and waves coming round its surface. From this observation Professor Milne showed that we can easily determine the distance of the seat of the disturbance from the recording instrument. By this means the correlation of two or three records from stations separated at sufficient distance gives the spot from which the disturbance radiated. But to-day that spot can be determined by one instrument alone. This discovery, as Professor Milne enthusiastically explains, was made by Prince Galitzin, a Russian seismologist, who points out that the first movement of the indicator is in the direction of the origin."

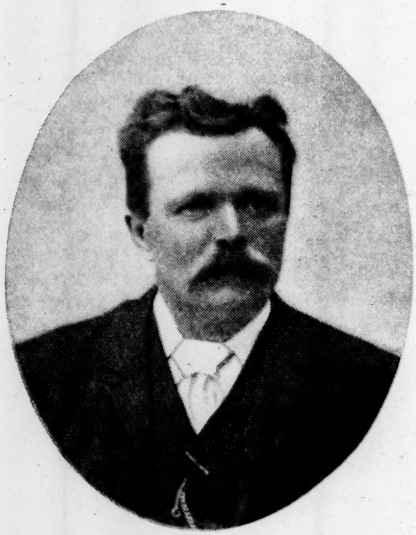
Professor Milne has certainly selected a spot for his home as far as may be from these earthquake disturbances which have made him famous. "It is a quaint conceit" (writes Mrs. Lou Henry Hover[1]) "that to the utter quiet of this pretty, tree-encircled old house, with its grassy stone-stepped terraces, leading down towards the little valley, with the great peaceful downs rising at its back, should come the earthquakes of the world to be classified and studied. But come they do, and a vast amount of work they make for Professor Milne and his clever Japanese assistant, Mr. Hirota".

Dr. Milne has been instrumental in establishing sixty or more seismological stations throughout the world, whose reports come some of them monthly, some twice yearly, and some when a chance boat brings them. These stations include Calcutta, Madras, Bombay, Cape of Good Hope, Adelaide, Melbourne, Sydney, Perth, Victoria, Australia, Fiji, Ascension, St. Helena, Seychelles, Mauritius, and Cocos Islands; in America there are stations at Baltimore, Philadelphia, Mexico, and the Argentine. In Argentina there will shortly be five stations. There is a seismological station at Honolulu and another on Fanning Island in the middle of the Pacific. As a rule the stations on isolated islands are erected and maintained by the Cable Companies, who recognize the benefits to be derived from Professor Milne's earthquake studies. There are a vast number of stations in Japan, and the Japanese Government expend £5,000 annually on seismographical research, and Russia does the same. There are several important seismological stations in Russia, including Tashkend, Tiflis, and

[1] Bulletin Seismological Society of America, Stanford University, California, vol. ii, No. 1, p. 5, March, 1912.

Irkutsk. In Chili they also spend a considerable sum annually on the science. Every six months a circular containing all the recent registers is sent out to all the stations. This is practically a labour of love on Professor Milne's part, for he holds no official position. He has already sent out forty-five of these circulars, as well as many other reports for the British Association, of whose Seismological Committee he has been honorary secretary for thirty-one years.

The wonderful success attending Professor Milne's work is of course owing to the fact that he is the inventor and designer of nearly all the apparatus in use in his laboratory at Shide, and not only there but in well-nigh every quarter of the globe.



Professor John Milne, D.Sc., F.R.S.
From a photograph taken in 1896.

Numerous investigations outside earthquakes have been carried on by Dr. Milne. In conjunction with his friend Mr. Macdonald, of the Japanese Railway Department, he perfected an instrument on the same principle as the seismograph for recording the vibrations of trains. By this means any defect in the engine or the permanent way can be at once discovered. These instruments are universally in use on Japanese railways, and will probably be taken up by British lines presently.

Notwithstanding the remoteness of Shide House, and the desire and necessity for quietude in order to carry out practically the various problems which Dr. Milne's active and inventive brain may suggest, his visitors' book shows that he has only imperfectly accomplished his object. From all parts of England these pilgrim questioners have come, from Scotland and from Ireland. All the great Universities are represented—Edinburgh, Glasgow, Cambridge, Oxford, Sheffield

University, University College, London, Bristol University, Tokyo, Jamaica, California, Corfu, Bermuda, Milan, Paris, Pennsylvania, and Greenwich Observatory. His visitors include the Presidents of many learned societies and Princes of various countries. His Majesty King George, who was then Prince of Wales, accompanied by the late Duke of Clarence, visited Dr. Milne's Earthquake Establishment in Japan, and the present Prince of Wales, while a cadet at the Royal Naval College, Osborne, visited the station at Shide.

It seems a lifetime to recall, as I am able, the days when Professor John Milne was a student at the Royal School of Mines, a keen young geologist and mineralogist, and an enthusiastic follower of Professor Sir Warington Smyth, his instructor.

What is the secret of his attractiveness and his perennial youth? It is the cheerful light-heartedness of his disposition, which has never deserted him in all these years, but has sustained his spirit and given him the power to infect others with the same interest and enthusiasm in his work and carry them along with him.

The phenomena of earthquakes are at once his serious study and his delightful occupation. For him the earth is like an Æolian harp, it vibrates to the influence of every heavenly body, it is played upon by the sun's tropic rays, buffeted by the unruly ocean in its lap, resounds to the stress of the storm-winds, is shaken by earthquakes and volcanoes from pole to pole, yet repeats, by a tender throb to his seismometer at Shide, the faintest vibration even from a distance of twelve thousand miles away.

H. W.

List of Publications by Professor J. Milne, D.Sc., F.R.S., F.G.S.[1]

1874. "Notes on the Physical Features and Mineralogy of Newfoundland": Quart. Journ. Geol. Soc., vol. xxx, pp. 722–45.
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1875. "Geological Notes on the Sinaitic Peninsula and North-Western Arabia": Quart. Journ. Geol. Soc., vol. xxxi, pp. 1–28.
1876. "Ice and Ice-work in Newfoundland": Geol. Mag., Vol. III (2), pp. 303–8, 345–50, 403–10.
1877. "On the Action of Coast-ice on an Oscillating Area": Quart. Journ. Geol. Soc., vol. xxxiii, pp. 929–31. [Abridged.]
"Considerations on the Flotation of Ice-bergs": Geol. Mag., Vol. IV (2), pp. 65–71.
(With Alexander Murray) "On the Rocks of Newfoundland": ibid., pp. 251–62.
"A Visit to the Volcanoes of Oshima": ibid., pp. 193–9.
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[1] Compiled by C. P. Chatwin, F.R.M.S.

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Sedgwick Museum Notes.

II.—Notes on the Genus *Trinucleus*.—Part I.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XVIII.)[1]

Introductory Remarks.

THE large collection of specimens of the various species of *Trinucleus* from British Ordovician beds which is available for study in the Sedgwick Museum offers unsurpassed opportunities for determining the characters of the members of this interesting genus as represented in

[1] Plate XIX will accompany the second part of this paper in the September Number.

the British Isles. The following notes have been compiled from a comparative study of this material supplemented by specimens from the Jermyn Street Museum and elsewhere. The frequent addition of specimens to the collection at Cambridge since Salter and McCoy's time have allowed for a more comprehensive and complete survey to be made than was then possible, though several doubtful points still await better material before they can be cleared up.

My attention was first directed several years ago to the inadequate or imperfect descriptions of the fringe; and accordingly the study of the structure of this portion of the head-shield forms the first paper in the series which is intended subsequently to deal with the other characters of the members of this genus, with a view to a revision of the British species.

I. The Fringe.

The structure of the 'fringe' around the head-shield of *Trinucleus* has been studied by many palæontologists from time to time, but in the case of the British species of the genus the investigation of its characters has sometimes lacked precision owing to the poorness or scarcity of the material available. Our knowledge, moreover, has mainly been confined to the upper surface of the fringe, and the features of its lower surface have very rarely been described. It is remarkable that it has not been more noticed that the upper and lower surfaces frequently show a considerable difference in the arrangement or development of the pits, so that casts of the two surfaces are dissimilar and lead to confusion in describing the specific characters unless this fact is clearly recognized.

From the examination of a large series of specimens of the principal British species it has been found possible to supply to some extent this gap in our knowledge, though some points in the structure and relation of the various types remain obscure for the present.

1. *Double Nature of the Fringe.*

With regard to the nature of the fringe itself, the presence of a marginal suture in all the species seems to be now generally assumed,[1] though its existence has not been always demonstrated, and in most of the British species can rarely be directly observed. We should expect it to be most clearly noticeable in those forms in which the fringe obviously consists of two lamellæ separated by an intervening space, as in the species from the Bala Beds of the Onny River, usually now referred to *T. concentricus*, Eaton. The suture in these specimens from Shropshire in which the shell is preserved is seen just above the angular outer edge, as Oehlert[2] states is the case in *T. Bureaui*, Oehlert. But the hourglass-shaped hollow pillars representing the opposite and communicating pits on the upper and lower surfaces are continuous and show no transverse plane of fission, though they break at the waist when the fringe is horizontally split; the internal tubes are also uninterrupted (Pl. XVIII, Figs. 1*a*, 1*b*).

[1] Woods, article on *Trilobita* in Camb. Nat. Hist., vol. iv, ch. viii, p. 226, 1909.

[2] Oehlert, Bull. Soc. Géol. France, ser. III, t. xxiii, p. 317, text-figs. *k* and *l*.

In the British forms referred to *T. seticornis*, His., or *T. Bucklandi*, Barr., those specimens which have the shell of the fringe preserved fail also to show a horizontal plane of fission traversing the tubes which likewise form continuous hollow pillars connecting the upper and lower lamellæ separated by an intermediate space. The same feature is observable in *T. Nicholsoni*, Reed. Probably the perforation and union of the upper and lower pits into complete tubes are of a secondary nature, and we may thus account for the obliteration of the median horizontal interlamellar space. Oehlert (op. cit.) does not consider that the lamellæ forming the upper and lower plates of the fringe were really completely perforated, or that direct communication by continuous canals was ever established; for he holds that a chitinous layer and conjunctive tissue existed on the inner side of each lamella, preventing a free passage. But the unbroken continuity of the tubes formed by corresponding pits can be distinctly observed without a shadow of doubt in transverse sections of the fringe of several British species, e.g. *T. subradiatus*, Reed, and it is particularly clear near the outer margin in this species and in those cases in which the lamellæ are nearly or quite in contact.

The duplicate nature of the fringe was indirectly recognized by Salter[1] in the case of *T. Lloydi*, Murchison, for he states the fringe is hollow in this species; though he had previously[2] put forward the incongruous view that the fringe originated by the lateral fusion of radial spines round the front of the head-shield. The presence of an internal cavity in *T. Lloydi* may, therefore, have been conjectured by him as due to the secondary hollowing out of a solid plate. Rouault,[3] though suggesting that the interlamellar cavity in the biconvex fringe of *T. Pongerardi*, Rouault, may have acted as a float, did not express the view that it resulted from the internal excavation of a simple thick plate.

If the fringe can be regarded as of the nature of an expanded border (upper lamella) and doublure (lower lamella) in a head-shield with a marginal suture, we should expect to find the inner edge of the doublure, i.e. the lower lamella or plate, free; and such is seen to be the case in well-preserved specimens of *Trinucleus*.

Whether a fusion of the two lamellæ has taken place in those cases in which the fringe seems solid and simple (e.g. *T. subradiatus*) is difficult to decide, as the shell is mostly unknown, but it may be regarded as probable. In other cases the lamellæ may have been so closely pressed together as to practically form one plate without definite fusion.

Beecher's view that the lower plate of the fringe represents the conjoint free cheeks of more highly specialized Trilobites need not be here discussed. At any rate, extensive modification in their structure must have subsequently taken place, if this theory is correct, and it is advisable to postpone the consideration of the homology and origin of the fringe till we have completed our study of the genus.

[1] Salter, Dec. Geol. Surv., No. vii, pl. vii, fig. 3, 1853.
[2] Salter, Proc. Geol. Soc., vol. iii, p. 251, text-figs., 1847.
[3] Rouault, Bull. Soc. Géol. France, ser. II, vol. iv, p. 311, pl. iii, figs. 1, 1*a–c*, 1846.

2. *Character of the Pits.*

The nature and development of the pits which dot the upper and lower surfaces of the fringe vary somewhat. Generally they are merely conical pits of greater or less depth, the apices of opposite and corresponding ones frequently touching one another and sometimes communicating by a pore, thus forming hourglass-shaped structures in a cross-section of the fringe. The pores when occurring at the apex of each pit may connect by means of a special minute pit or short tube, or the apices may be directly in contact. Occasionally the floor of each pit is raised in the centre into a low rounded boss or mamelon, the centre of which is depressed and perforated, and it is connected with the corresponding pit on the opposite surface by a short fine tube, as is beautifully shown in some casts of the so-called *T. concentricus* from the Onny River (Pl. XVIII, Fig. 1). The same structure is observable in the larger pits at the genal expansions in most British specimens of *T. seticornis*, and in *T. Bucklandi* from Girvan. Barrande[1] did not show this plainly in his figures of *T. Bucklandi* from Bohemia. In his figures of *T. ornatus* (op. cit., pl. xxix, figs. 7, 8), he illustrated the common type of pit in the genus, consisting of a subconical circular depression with a small pore in the centre of the floor.

3. *Arrangement of the Pits.*

The pits of successive concentric rows are in some cases sunk in radial grooves or may be fused more or less completely so as to form radial sulci. In the most extreme cases (e.g. *T. hibernicus*, Reed[2]) the pits completely lose their identity and the perforations then alone indicate the number of pits which have amalgamated (Pl. XVIII, Fig. 2). All stages between the simple linear arrangement of pits in radial lines and their depression into grooves and fusion can be traced; and the definiteness, straightness, and elevation of the dividing radial ridges likewise vary from the extreme development of *T. fimbriatus*, Murchison,[3] to the scarcely differentiated structures in *T. Nicholsoni*.[4] Frequently different stages occur in the same species or in different parts of the fringe of the same individual (e.g. *T. Murchisoni*, Salter[5]).

The increase in the number of pits in the same concentric row is brought about by intercalation, and this intercalation does not seem to take place at any definite point in the row, judging from those cases (e.g. *T. concentricus* from the Onny River) in which it has been most clearly observed in the marginal (i.e. outermost) row (Pl. XVIII, Figs. 4, 7, 12).

On the other hand, the addition to the number of concentric rows

[1] Barrande, Syst. Silur. Bohême, vol. i, pl. xxix, figs. 10–17; pl. xxx, figs. 14–16.

[2] Reed, GEOL. MAG., Dec. IV, Vol. II, p. 52, Pl. III, Figs. 2–7, 1895.

[3] Murchison, Silur. Syst., t. xxiii, fig. 2 (head only); McCoy, Syn. Brit. Pal. Foss. Woodw. Mus., p. 146, pl. 1E, fig. 16.

[4] Reed, GEOL. MAG., Dec. V, Vol. VII, p. 212, Pl. XVI, 1910.

[5] Salter, Siluria, 2nd ed., p. 50, fig. 7; id., Mem. Geol. Surv., vol. iii, p. 515, pl. xiB, fig. 4.

as distinct from the addition to the number of pits in the same row has so far been always traced to the division of one of the pits, and the new row starts off from the inner half of such a transversely bisected pit (Pl. XVIII, Figs. 5, 11). Such is the origin of the second row in the case of *T. Bucklandi* and of the extra rows of small pits on the 'roll' of the fringe of *T. seticornis*. Pits arising in this way by fission lie in the same radial lines as those of the originating row, but those developed by intercalation in the same row disturb the regular radial arrangement and lead to alternation in the pits of successive rows or to irregularity in their arrangement.

The base of the glabella is not always the centre of the circle to which the radial lines of pits in the fringe converge. The point of convergence may be situated further forward, and towards the genal angles the lines may therefore slope back, giving a fan-like arrangement. If the pits are not in sunken grooves this shifting forward of the centre leads to the appearance of alternation of pits in successive rows as the genal angles are approached (e.g. *T. Lloydi*).

With regard to the pits on the expansions of the fringe at the genal angles or posterior outer angles of the cheeks, there seems to be no definite rule; in all the species they are added and interpolated irregularly, and even in the same species there is considerable variation in their number and position which is not entirely due to differences of age.

4. *Differences in the Upper and Lower Surfaces of the Fringe.*

The upper and lower surfaces of the fringe in many species of *Trinucleus* show a considerable difference in the development and arrangement of the pits, as Salter long ago noticed. The concentric rows on the two surfaces may or may not correspond even in number, and radial grooves may only be developed on one surface and not on the other or in different parts of the two surfaces. The aspect of the two surfaces is therefore frequently different, and this is especially noticeable in the case of impressions of the surface. In most specific descriptions, however, only the characters of the upper surface are recorded, and unfortunately this is occasionally unavoidable owing to our imperfect knowledge of the lower surface.

4*a*. *Lower Surface of Fringe.*

With regard to the lower surface of the inferior lamella or plate of the fringe, we may first note that it is rarely either uniformly flat or gently convex or weakly concave as is the upper lamella. In nearly every case it is more or less angulated at one of the concentric ridges some distance inwards from the outer edge. This angulation may be feebly marked, particularly near the genal angles (e.g. *T. Goldfussi*, Barrande), or it may be quite absent (*T. Pongerardi*), but usually traces of it are discernible. Where it is strongly developed the division of the lower surface into an outer more or less horizontal flat band and into an inner inclined flat or more generally concave band is at once noticeable. Usually these bands are of unequal width, the outer one being generally of regular and smaller width and the inner one variable but widening considerably towards the genal angles and

there corresponding to the genal expansions at the inner edge of the upper lamella. The distribution and character of the pits on the two bands have generally marked peculiarities, as will be mentioned in the sequel.

4*b*. *The Outer and Inner Bands.*

The division into an outer and an inner band is well seen in *T. Murchisoni*, *T. fimbriatus*, *T. hibernicus*, *T. Bucklandi*, *T. seticornis*, *T. Nicholsoni*, and *T. subradiatus*.

The two portions or bands are separated as a rule not only by an angular junction but also by the marked enlargement or thickening of the concentric ridge situated along this line. This specially developed ridge may be termed for convenience the 'girder', as it appears to have been formed for strengthening purposes; it is particularly well seen in the British examples of *T. seticornis* and *T. Bucklandi*, but it occurs more or less strongly developed in all the species possessing an outer and inner band to the lower plate. Salter[1] briefly noticed and figured it in *T. Lloydi* and in *T. concentricus*,[2] but Nicholson and Etheridge, jun.,[3] described it as a groove instead of a ridge in the Girvan examples of *T. Bucklandi*, forming their ideas from impressions of the lower plate. Bernard Smith[4] mentioned it also as a groove in connexion with *T. Portlocki*, Salter, from Tyrone, but for the most part this structure seems to have been ignored. The author described it as a ridge in the case of *T. Nicholsoni*.[5]

4*c*. *The Position of the Girder.*

The position of the girder in relation to the concentric rows of pits on the lower surface varies to some extent in different species. In *T. Lloydi* Salter showed the girder lying inside the two outermost rows, and this is found to be the commonest position, and he described[6] also the British form of *T. concentricus* as having the girder similarly placed, i.e. between the second and third rows. This may be well seen in most Welsh examples from Bala Beds, but in those from Pwllheli the girder is not clearly differentiated, the concentric ridge between the third and fourth rows being nearly as strong as that between the second and third rows. In *T. concentricus* from the Onny River it is interesting to find the girder readily recognizable by reason of its greater strength inside the second row in the anterior median part of the fringe, but posteriorly on each side it decreases in size and is scarcely larger than the ridge inside the first row.

In *T. subradiatus*[7] the first and second concentric ridges are of equal or subequal size (though in front the ridge behind the first row is most pronounced), the girder thus not being clearly differentiated;

[1] Salter, Dec. Geol. Surv., No. vii, pl. vii, 1853.
[2] Salter, Mem. Geol. Surv., vol. iii, p. 517, pl. xix, figs. 4, 4*a*.
[3] Nicholson & Etheridge, jun., Mon. Girvan Silur. Foss., fasc. ii, p. 192, 1882.
[4] Fearnsides, Elles, & Smith, Proc. Roy. Irish Acad., vol. xxvi, sect. B, No. 9, p. 122, 1907.
[5] Reed, GEOL. MAG., Dec. V, Vol. VII, p. 212, 1910.
[6] Salter, Mem. Geol. Surv., vol. iii, p. 517, pl. xix, figs. 4, 4*a*.
[7] Reed, Mon. Girvan Trilob. (Palæont. Soc.), pt. i, p. 12, pl. ii, figs. 2, 5, 6.

but as the inner plate bends up immediately behind the second ridge it is probable that this one represents the girder of other species.

In the allied species *T. ornatus* and *T. Goldfussi* from Bohemia there is seen to be no distinguishable girder, the ridges being equal and the lamella not bent, as Barrande figured.[1]

In *T. Nicholsoni*[2] the girder is strongly developed inside the second row (Pl. XVIII, Fig. 6), and the same position is found in specimens of *T. seticornis* from Rhiwlas, Norber Brow, Applethwaite, Sholeshook, Redhill, etc.

In *T. Bucklandi* from Girvan the girder is equally well developed, and has the same position, but this is not the case in immature individuals in front where only one row of pits is present (see sequel). The same peculiarity is noticeable in specimens of *T. seticornis* from the *Trinucleus* Shales of Nitsjo, Dalarne.

In *T. Murchisoni* there is a well-marked girder inside the series of radial grooves on the outer band, each of which holds three pits in a line (Pl. XVIII, Fig. 11). It is similarly situated, but narrower, in *T. Etheridgei*.

The position of the girder inside the first concentric row is found in *T. Portlocki* from Tyrone, as is well shown in B. Smith's figure,[3] and the type-specimen of Portlock's *T. elongatus*[4] likewise has the girder in the same position.

T. favus, Salter, has the strongest of its concentric ridges inside the first row (Pl. XVIII, Fig. 9), and the same is noticeable in American specimens of *T. concentricus* from the Utica Slate.

In *T. fimbriatus* the lower surface of the fringe (Pl. XVIII, Fig. 10), which is quite unlike the upper one in the character of its pitting (see sequel), has a broad outer band with only one marginal row of pits and no radial grooves; inside this row the outer band is smooth and devoid of pits to the line of bending, which is sharp but not marked by any thickening or distinct girder.

T. hibernicus has a somewhat similar wide smooth flat space on the outer band behind the two rows of small sunken radially arranged pits in weak sulci (Pl. XVIII, Fig. 2); the junction with the inner band is likewise angulated and sharply defined, but without any raised ridge or thickening.

EXPLANATION OF PLATE XVIII.

FIG. 1. *Trinucleus concentricus* (Eaton). Middle Bala: Onny River, Shropshire. Impression of part of upper lamella of fringe. × 6.

,, 1*a*. Ditto. Diagrammatic section of upper and lower lamellæ, showing canals between opposite pits.

,, 1*b*. Ditto. Natural section across fringe, showing interlamellar space with connecting 'pillars' formed by union of opposite pits. × 6.

,, 2. *T. hibernicus*, Reed. Tramore Limestones: Tramore, co. Waterford. Portion of upper surface of fringe, showing pits fused and sunk in radial sulci. × 6.

[1] Barrande, Syst. Silur. Bohême, vol. i, pls. xxix, xxx.

[2] Reed, GEOL. MAG., Dec. V, Vol. VII, p. 212, Pl. XVI, 1910.

[3] Fearnsides, Elles, & Smith, Proc. Roy. Irish Acad., vol. xxvi, sect. B, No. 9, p. 121, pl. viii, fig. 1, 1907.

[4] Portlock, Geol. Rep. Londond., p. 263, pl. i B, fig. 6.

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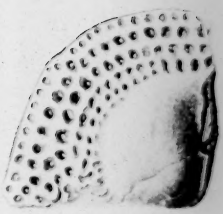
1a

1b

2



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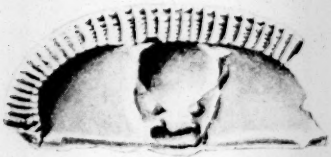

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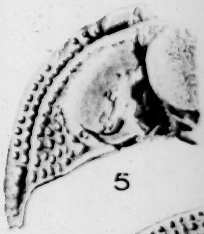

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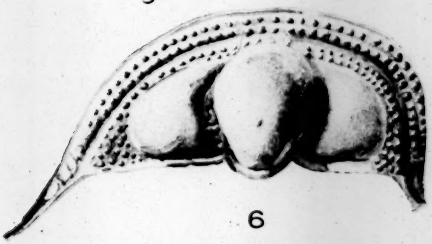

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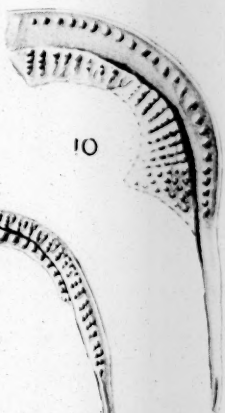

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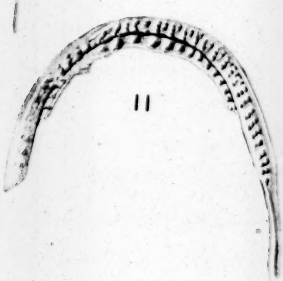

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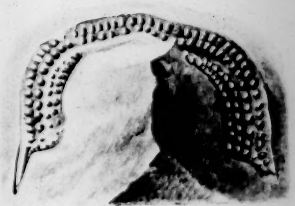

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T. C. Brock del.

British Ordovician species of *Trinucleus*.

FIG. 3. *T. fimbriatus*, Murchison. Llandeilo: Gwernyfedfach, Builth. Impression of upper surface of fringe, showing pits in radial grooves. × 2½.

,, 4. *T. concentricus* (Eaton). Middle Bala: Cheney Longville. Portion of upper surface of fringe, showing increase in number of pits of first row by intercalation. × 2½.

,, 5. *T. seticornis* (Hisinger). Coniston Limestone Series: Applethwaite Common. Impression of portion of lower surface of fringe, showing 'girder' and increase in number of rows on outer band by fission of pits. × 2½.

,, 6. *T. Nicholsoni*, Reed. Dufton Shales: near Melmerby. Impression of lower surface of fringe, showing girder, etc. × 2½.

,, 6*a*. Ditto. Impression of upper surface of fringe, showing radial arrangement of pits. × 2½.

,, 7. *T. concentricus* (Eaton). Middle Bala: Onny River. Lower surface of fringe, showing girder feebly differentiated in median portion, and intercalation of pits in outermost row. × 2½.

,, 8. *T. subradiatus*, Reed. Balclatchie Beds: Dow Hill, Girvan. Portion of lower surface of fringe (and impression of part of upper surface), showing undifferentiated girder, etc. × 2½.

,, 9. *T. favus*, Salter. Llandeilo Beds: Meadowtown. Impression of part of lower surface of fringe, showing position of girder inside first row of pits. × 2½.

,, 10. *T. fimbriatus*, Murchison. Llandeilo: Gwernyfedfach, Builth. Impression of lower surface of fringe, showing single row of pits on outer band and radial grooves on inner band (partly restored from other specimens). × 2½.

,, 11. *T. Murchisoni*, Salter. Upper Arenig: Tasker Quarry, Shelve. Impression of lower surface of fringe, showing primary and secondary radii on outer band, girder and single row of pits on inner band in front splitting into two rows at sides. × 2½.

,, 12. *T. concentricus* (Eaton). Middle Bala: Onny River. Impression of lower surface of fringe, showing irregularity of radial arrangement. × 2½.

III.—The Cirripede '*Brachylepas cretacea*', H. Woodward.

By Thomas H. Withers, F.G.S.

(PLATE XX.)

(*Concluded from the July Number, p. 326.*)

In addition to the valves from Lüneburg herein mentioned, it has been possible to examine the more important of the material described by previous authors, namely: (1) the valve figured by H. Woodward (1868) as *Pyrgoma cretacea*, and subsequently (1901) as *Brachylepas cretacea*, now in the British Museum (Natural History), registered I. 14029; (2) the nearly complete capitulum figured as *B. cretacea* by H. Woodward (1901), in the collection of Dr. A. W. Rowe, of Margate; (3) the valve figured by Marsson (1880) as *Pollicipes cancellatus*, together with other valves studied by him, now in the Geologisches Landesmuseum of Berlin; (4) the valve figured by Quenstedt (1883) as *P. lævissimus*,[1] now in the University of Tübingen; (5) the valve mentioned by Boehm (1906), in the Geologisches Landesmuseum of Berlin; and (6) a large number of more or less

[1] I have been unable to ascertain the whereabouts of the series of valves figured as *Pollicipes lævissimus* by Zittel. Dr. E. Dacqué kindly informs me that they are not in the collection of the Palæontological Museum, Munich.

broken carinæ and rostra, with several scuta and terga, obtained from the Chalk of Rügen by Mrs. Agnes Laur, and acquired by the British Museum (Natural History).

Examination of this material leaves little doubt that a single widely-distributed but variable form is represented, and young valves identical with the original of *Emarginula* (?) *Naissanti* can be seen among the valves from Rügen. The Lüneburg valves are on the whole rather less strongly ornamented than those from other countries, and this is possibly due to difference in habitat; but there is some considerable variation in the sharpness of the longitudinal and transverse ridges of the carinæ and rostra from Rügen and England.

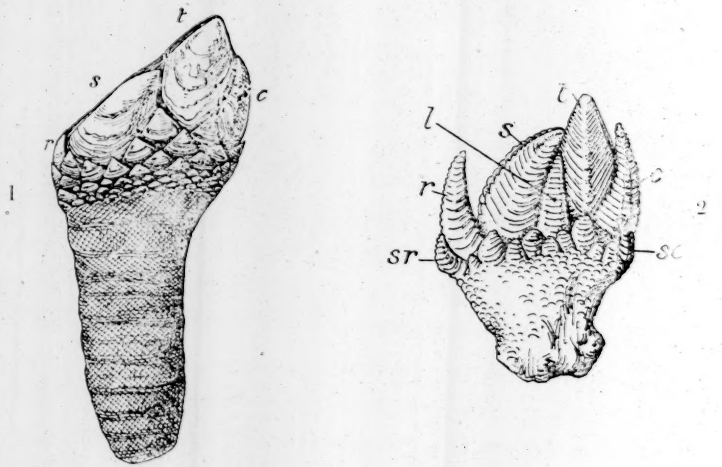


Fig. 1. *Pollicipes polymerus*, G. B. Sowerby. Living: Upper California, Pacific, etc. (After Darwin.) Capitulum with two or more whorls of valves under the rostrum; latera gradually increasing in size towards the capitulum; peduncle generally two or three times as long as the capitulum.

,, 2. *P. mitella*, Linnæus. Living: Philippines, China, etc. (After Darwin.) Capitulum with one whorl of valves only under the rostrum; upper latera very narrow, three or four times as long as the lower latera, which overlap each other laterally; peduncle usually as long as the capitulum, but in some cases considerably shorter.

The carina and rostrum of *Brachylepas Naissanti* differ widely in shape from the same valves of *Pollicipes fallax*, now referred by H. Woodward to the genus *Brachylepas* (1906), being much more squat and semicircular, and their characteristic ornament readily distinguishes even small fragments. The scuta, terga, and upper latera of *B. Naissanti*, however, are very similar to the homologous valves of *P. fallax*. The only difference as regards the terga and upper latera, so far as one can judge from the few valves of *P. fallax* that have been examined, is that in *B. Naissanti* the transverse ridges or zones of growth are not nearly so strongly marked, and the basal portion of the terga is much more acute. The scuta of

B. Naissanti differ mainly in that, instead of having a sharp ridge with sloping sides extending from the apex to the basal angle as in *P. fallax*, there is a prominent fold which on the tergal side is abruptly folded downwards and inwards, as indicated in the transverse section (Fig. 3*a'*). The transverse ridges are not so prominent as in *P. fallax*.

In the remarkable specimen upon which Dr. H. Woodward (1901) founded the genus *Brachylepas* the more important of the valves of the capitulum are absent, and the specimen consists of the carina and rostrum, kept in position by three or four rows of imbricating plates encircling their bases. There is evidently no distinct sub-carina or sub-rostrum. Although Dr. Woodward refers in the early part of his paper to the absent valves as "the opercular valves", he subsequently says: "It seems much more probable that the scuta and terga, and perhaps a small and narrow latus, took part, as in *Pollicipes*, in building up the capitulum, the basis of which was

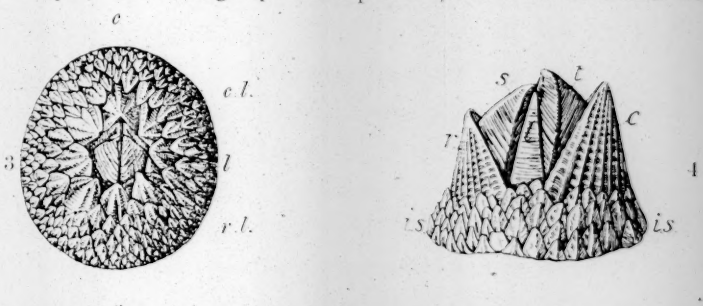


Fig. 3. *Catophragmus polymerus*, Darwin. Living: Australian coast. (After Darwin.) Interior compartments eight, with several exterior whorls of compartments, which in old specimens number ten or even more; basis membranous.

,, 4. *Brachylepas Naissanti*, Hébert sp. Upper Senonian: England, France, Germany, etc. Restored capitulum. Capitulum comprising an upper whorl of eight valves consisting of a carina, rostrum, paired scuta, paired terga, and paired upper latera, with four whorls of imbricating valves below the rostrum; no distinct sub-carina or sub-rostrum; outer whorls of valves (probably three) possessing an inwardly projecting basal ledge, which is fixed into the median notch of the valve immediately in front of it, together forming a shelf or platform round the base of the capitulum; basis probably membranous.

This restoration is based on the valves from Lüneburg, which were found embedded together in a small piece of chalk. The number and position of the lower whorls of plates is based on the figure given by Dr. H. Woodward in his paper (1901). *r.* rostrum; *s.* scutum; *t.* tergum; *c.* carina; *l.* upper latus; *s.r.* sub-rostrum; *s.c.* sub-carina; *c.l.* carinal latus; *r.l.* rostral latus; *i.s.* imbricating plates.

protected by a series of imbricated shelly plates." He further says: "From the disparity in the proportions of the rostrum and carina and the absence of alæ, we arrive at the conclusion that the terga and scuta were not mere opercular valves, but formed a part of the capitulum."

From a study of the new material from Lüneburg, including the scuta, terga, and upper latera, it is evident that the capitulum must have been built up in the manner suggested by Dr. Woodward. The upper latera, however, are rather different, being somewhat larger and narrower than is indicated by the hypothetical figure in his restoration; they closely resemble the homologous valves of *P. fallax* and of the recent *P. mitella* (see Text-fig. 2).

We have now certain knowledge of the whole of the valves that formed the capitulum of *B. Naissanti* (see restoration, Text-fig. 4), and a comparison of the isolated valves with those of the recent *P. mitella* shows how extraordinarily alike the upper whorl of valves is in its structure and arrangement. It is especially noticeable that the upper latera are of the same type. In *B. Naissanti* the lines of growth on the inner surfaces of the carina and rostrum show that the upper part of these valves must have projected freely, the rostrum to a greater extent proportionally than the carina. The scuta and terga undoubtedly articulated together, and the greater portion of the upper latera must have overlapped the scuta and terga, since only a small triangular portion of its base appears to have been covered by the membrane (corium) lining the inside of the valves of the capitulum. In fact, the upper and main whorl of valves had precisely the same method of arrangement as in *P. mitella*. As one would naturally expect, the valves of *B. Naissanti* differ somewhat in shape from those of *P. mitella*, the most important differences being that the rostrum and carina are more squat and semicircular, approaching in this respect the sessile forms of Cirripedes, although they do not possess radii or alæ; the scuta differ mainly in having a straight basal margin. In the case of *P. mitella* (see Text-fig. 2) it will be seen that there is only one whorl of valves below the rostrum, including a sub-carina and sub-rostrum, whereas in *B. Naissanti* (see Text-fig. 4) there are at least four whorls of imbricating plates, with no sub-carina or sub-rostrum, an arrangement that reminds one of the base of the capitulum in the sessile Cirripede *Catophragmus* (see Text-fig. 3), in which old individuals have as many as ten or even more whorls of valves. The most important character of *B. Naissanti* and one of great significance, although it does not appear to have been described previously, is that the two and possibly three outermost whorls of imbricating valves have a basal ledge which projects inwards and is fixed by its somewhat acute inner extremity into a median notch at the base of the valve immediately in front of it. The valves of the innermost whorl have no such basal ledge, but have a median notch at the base, by which they are fixed externally to the projecting ledge of the surrounding whorl of valves. These basal ledges lie almost on the same plane, together forming a shelf or platform extending round the base of the capitulum. The formation of this platform seems to preclude the possibility of *B. Naissanti* having had a peduncle, and the probability is that it had a membranous basis and that the outer whorls of valves were in close proximity to the surface of attachment, as are the outer whorls of valves in the recent *Catophragmus polymerus*. Firm attachment for the membranous basis may have been afforded by the edges of the laminæ which stand out as sharp ridges on the lower

surface of the basal ledges. In *C. polymerus* the outer whorls of valves are quite thin at their base, and there is a definite space bounded by the concave inner margin of each valve, the basis being membranous. Only two other species of *Catophragmus* besides *C. polymerus* have yet been discovered, namely, *C. imbricatus*, Sowerby, and *C. Darwini*, Pilsbry; the basis of *C. Darwini* is unknown, while that of *C. imbricatus* is calcareous. The basis of *B. Naissanti* was probably membranous, and in addition the basal ledges of the outer whorls of valves together formed a narrow shelf or platform round the base of the capitulum. This shelf, however, is formed by the ingrowth of the valves and by their interlocking. In the Balanidæ proper (*Balanus*) the calcareous basis is a separate part of the shell, and is added to exteriorly during the growth of the upper compartments.

Darwin[1] has already observed how nearly related *P. mitella* is to the sessile Cirripedes, and of *Catophragmus*[2] he remarked—

"This genus is very remarkable among sessile Cirripedes, from the eight normal compartments of the shell being surrounded by several whorls of supplemental compartments or scales: these are arranged symmetrically, and decrease in size but increase in number towards the circumference and basal margin. A well-preserved specimen has a very elegant appearance, like certain compound flowers, which when half open are surrounded by imbricated and graduated scales. The Chthamalinæ, in the structure of the mouth and cirri, and to a certain extent in that of the shell, fill up the interval between the Balaninæ and Lepadidæ; and *Catophragmus* forms, in a very remarkable manner, the transitional link, for it is impossible not to be struck with the resemblance of its shell with the capitulum of *Pollicipes*. In *Pollicipes*, at least in certain species, the scuta and terga are articulated together—the carina, rostrum, and three pairs of latera, making altogether eight inner valves, are considerably larger than those in the outer whorls—the arrangement of the latter, their manner of growth, and union, all are as in *Catophragmus*. If we in imagination unite some of the characters found in the different species of *Pollicipes*, and then make the peduncle so short (and it sometimes is very short in *P. mitella* [see Text-fig. 2]) that the valves of the capitulum should touch the surface of attachment, it would be impossible to point out a single external character by which the two genera in these two distinct families could be distinguished: but the more important differences in the arrangement and nature of the muscles, which are attached either to the opercular valves or surround the inside of the peduncle, would yet remain."

Whilst, as Darwin points out, the Chthamalinæ (*Catophragmus*) link up the Lepadidæ with the Balanidæ, so the fossil *B. Naissanti* presents features in common with the Lepadidæ as represented by *Pollicipes mitella*, and the Balanidæ as represented by *Catophragmus* of the sub-family Chthamalinæ. The finding of the remaining valves of the capitulum proves that the upper whorl of valves had in *B. Naissanti* precisely the same structure and arrangement as in the recent *P. mitella*, and in this respect it is allied to *Pollicipes*, although the carina and rostrum by their structure and near equality in size suggest that the animal was assuming a more sessile condition of growth. In the presence of several whorls of imbricating plates at

[1] "A Monograph on the Fossil Lepadidæ": Palæontographical Society, 1851, p. 48.

[2] "A Monograph of the Sub-class Cirripedia, the Balanidæ, etc.": Ray Society, 1854, pp. 485–6.

the base of the capitulum, *B. Naissanti* has a close outward resemblance to the sessile Cirripede *C. polymerus*, but the presence of these basal whorls of valves distinguishes it from the Balanidæ proper (*Balanus*), since they have no such basal whorls of valves. The discovery of the inwardly projecting ledge to the valves of the basal whorls in *B. Naissanti*, and their method of interlocking to form a narrow shelf or platform round the base of the capitulum, shows that these valves are quite different from those of *C. polymerus*, for in that species there is a definite space bounded by the concave inner margin of each valve. It is not quite clear from Dr. H. Woodward's paper (1901) whether he definitely regarded *B. Naissanti* as a sessile Cirripede, although he recognized its relationship to the sessile forms, but the modification of the basal whorls of valves in *B. Naissanti* to form a shelf or platform round the base of the capitulum leaves little doubt in my mind as to the sessile nature of this species.

For their kindness in loaning or procuring the loan of specimens, or for their assistance in connexion with this paper, I wish to express my indebtedness to Dr. F. A. Bather, Dr. J. Boehm, Dr. W. T. Calman, Mr. C. P. Chatwin, Dr. P. P. C. Hoek, Dr. F. v. Huene, Dr. A. W. Rowe, and Mr. C. Davies Sherborn.

EXPLANATION OF PLATE XX.

FIG.

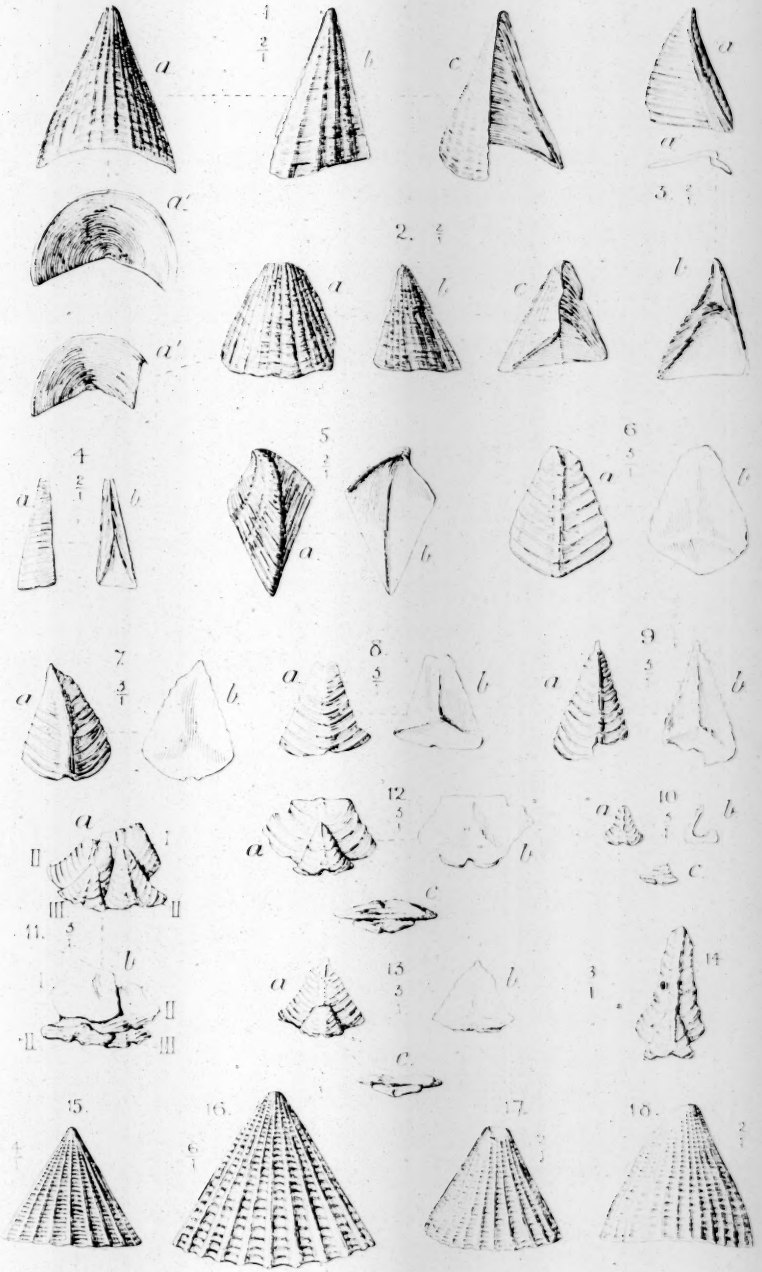
1. *Brachylepas Naissanti*, Hébert sp. Carina. *a*. outer view; *a'*. basal view; *b*. side view; *c*. inner view. Upper Senonian (*Belemnitella mucronata*-zone): Lüneburg, Hanover.
2. Id. Rostrum. *a*. outer view; *a'*. basal view; *b*. side view; *c*. inner view.
3. Id. Scutum. *a*. outer view; *a'*. transverse section; *b*. inner view.
4. Id. Upper latus. *a*. outer view; *b*. inner view.
5. Id. Tergum. *a*. outer view; *b*. inner view.
6. Id. One of the imbricating valves without a basal ledge. (Probably from a position below the upper latus.) *a*. outer view; *b*. inner view.

7–9. Id. Imbricating valves of the innermost whorl. *a*. outer view; *b*. inner view. (Fig. 7 probably occupied a position near the region of the upper latera, and Figs. 8 and 9 either at the carina or rostral end of the capitulum.)

10. Id. An imbricating valve; possibly of the second whorl; the basal ledge is wider than in most valves, and its upturned inner extremity is adapted to fix into the median notch of the valve in front of it. *a*. outer view; *b*. side view; *c*. basal view showing the ledge.
11. Id. Four of the imbricating valves still attached to one another, showing their external arrangement and the method of interlocking of the basal ledges to form the shelf or platform round the base of the capitulum. (Probably from a position below the upper latera.) *a*. outer view; *b*. inner view. I, a valve of the innermost whorl without a basal ledge; II, two valves of the second whorl with a basal ledge; III, a valve of the third whorl with a basal ledge.

12, 13. Id. Two pairs of imbricating valves, still attached to each other. (Probably of the first and second whorls.) *a*. outer view; *b*. inner view; *c*. basal view showing the basal ledge.

14. Id. Two imbricating valves still attached. Outer view. (Probably from near the region of the carina.)
15. *B. Naissanti*, Hébert sp. Carina, outer view. Upper Senonian (*B. mucronata*-zone): Meudon, France. Copy of the original figure of *Emarginula* (?) *Naissanti*, Hébert, Mém. Soc. Géol. France, 2e sér., vol. v, pl. xxix, fig. 10, 1855.



W. Woodward del.

Brachylepas Naissati, Hébert sp., a Cretaceous Cirripede.

FIG.

16. *B. Naissanti*, Hébert sp. Carina, outer view. Upper Senonian (*B. mucronata*-zone): Isle of Rügen. Copy of the original figure of *Pollicipes cancellatus*, Marsson, Cirrip. d. Weiss. Schreib.-Kreide d. Rügen, 1880, pl. ii, fig. 7.
17. *B. Naissanti*, Hébert sp. Rostrum, outer view. Upper Senonian (*B. mucronata*-zone): Haldem, Westphalia. This is the valve mentioned by J. Boehm, Centralbl. f. Min., 1906, p. 449, in the Geologisches Landesmuseum of Berlin.
18. *B. Naissanti*, Hébert sp. Carina, outer view. Upper Senonian (*B. mucronata*-zone): near Norwich, Norfolk. This is the original valve figured by H. Woodward as *Pyrgoma cretacea* (GEOL. MAG., 1868, Pl. XIV, Figs. 1, 2), and as *Brachylepas cretacea* (GEOL. MAG., 1901, Pl. VIII, Figs. 3, 4; 1906, p. 337).

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IV.—On the Recognition of Two Stages in the Upper Chalk.

By A. J. Jukes-Browne, F.R.S., F.G.S.

(*Concluded from the July Number, p. 313.*)

THE next step is to see if the evidence of the Echinodermata coincides with and confirms that of the Cephalopoda. The Echinoderms will be tabulated in the same way as the Cephalopoda, beginning with those of Germany. The following table has been compiled from several sources, and may not be quite complete as regards the irregular forms, though it is practically so for the Regulares, this part being taken from Schlüter's monograph on that order:—

TABLE IV.

Echinodermata in North Germany.

Species.	*Cuvieri* zone.	The *Emscher*.	Zone of *Marsupites*.	Zone of *S. hinsbossus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Cidaris Merceyi, Cott.	x	-	-	-	-	-
C. sceptrifera, Mant.	x	x	-	-	-	-
C. hirudo, Sorig	-	-	-	x	-	-
C. ? pistillum, Quendst.	-	-	-	-	-	x
C. pseudopistillum, Cott.	-	-	-	x	-	-
C. Herthæ, Schlüter	-	-	-	-	-	x
C. mammillata, Cott.	-	-	-	-	-	x
C. gigas, Schlüter	-	-	-	-	-	x
C. darupensis, Schlüter	-	-	-	-	-	x
C. cometes, Boll	-	-	-	-	-	x
C. striatula, v. d. Marck	-	-	-	-	-	x
C. alata, Boll	-	-	-	-	-	x
C. spinosa, Boll	-	-	-	-	-	x
C. baltica, Schlüter	-	-	-	-	-	x
C. Faujasi, Desor	-	-	-	-	-	x
C. cf. *Hardouini*, Desor	-	-	-	-	-	x
C. Gosæ, Schlüter (=*clavigera*, part)	-	-	-	x	-	-
C. vexillifera, Schlüter	-	-	-	-	-	x
Temnocideras Baylei, Cott.	-	-	-	-	-	x
T. danica, Cott.	-	-	-	-	-	x
Porocidaris lingualis, Desor	-	-	-	-	-	x
Pleurocidaris regalis, Goldf.	-	-	-	-	-	x
Salenia gehrdensis, Schlüter	-	-	-	x	-	-
S. Quendstedti, Schlüter	-	-	-	x	-	-
S. Heberti, Cott.	-	-	-	-	x	-
S. obnupta, Schlüter	-	-	-	-	-	x
S. anthophora, Müll. (=*Bonissenti*, Cott.)	-	-	-	-	-	x
S. stellifera, Hagen.	-	-	-	-	-	x
S. pygmæa, Hagen.	-	-	-	-	-	x
S. maestrichtensis, Schlüter	-	-	-	-	-	x
Peltastes heliophorus, Ag.	-	-	-	-	-	x
Cyphosoma radiatum, Sorig	x	x	x	-	-	-
C. spathuliferum, Forbes	-	x	-	-	-	-
C. gehrdense, Schlüter	-	-	-	x	-	-
C. cf. *magnificum*, Ag.	-	-	-	x	-	-
C. ornatissimum, Ag.	-	-	-	-	-	x

Species.	*Cuvieri* zone.	The *Emscher*.	Zone of *Marsupites*.	Zone of *S. binodosus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Cyphosoma princeps, Hagen.	-	-	-	-	-	x
C. tæniatum, Hagen.	-	-	-	-	-	x
C. pseudoradiatum, Schlüter	-	-	-	-	-	x
C. polygophorum, Schlüter	-	-	-	-	-	x
Echinocyphus tenuistriatus, Desor	-	-	-	x	-	-
Zeuglopleurus pusilla, Röm.	-	-	-	x	-	-
Goniopygus Heberti, Cott.	-	-	-	-	-	x
Phymechinus cretaceus, Schlüter	-	-	-	-	-	x
Diplotagma altum, Schlüter	-	-	-	-	-	x
Catopygus obtusus, Desor	-	-	x	x	-	-
Caratomus truncatus, d'Orb.	-	-	-	-	x	-
Micraster coranguinum, Leske	-	x	x	-	-	-
M. cortestudinarium, Goldf.	x	-	-	-	-	-
M. gibbus, Lam. (*Epiaster*)	-	-	-	x	x	x
M. glyphus, Cott.	-	-	-	-	x	x
M. Haasi, Stolley	-	-	-	-	x	-
M. Gotschei, Stolley	-	-	-	-	x	-
M. Schroderi, Stolley	-	-	-	-	x	-
Epiaster brevis, Desor	x	-	-	-	-	-
Ananchytes vulgaris, var. *conica*	-	-	-	-	x	x
A. vulgaris, var. *gibba*	-	x	-	-	x	-
A. vulgaris, var. *ovata*	-	-	x	x	x	x
A. vulgaris, var. *conoidea*	-	-	-	-	x	x
Galerites albogalerus, Leske	-	x	-	x	-	x
G. Roemeri (=*abbreviatus*, Desor)	-	-	-	-	-	x
Offaster pilula, Lam.	-	-	-	-	x	-
O. corculum, Goldf.	-	-	-	-	-	x
Cardiaster granulosus, Goldf.	-	-	-	x	x	x
C. jugatus, Schlüter	-	-	x	-	-	-
C. Heberti, Cott. (=*maximus*, Schlüter)	-	-	-	-	x	x
Hemiaster ligeriensis, d'Orb.	-	-	-	x	-	-
H. recklinghausensis, Schlüter	-	-	x	-	-	-
Tygurus rostratus, Röm.	-	-	x	-	-	-
Marsupites testudinarius, Schloth.	-	-	x	-	-	-
Uintacrinus westfalicus, Schlüter	-	-	x	-	-	-
Bourgueticrinus ellipticus, Müll.	-	-	x	x	x	-

From this table it will be seen that there are two different Echinoderm faunas in Germany, just as there are two different Cephalopodan faunas, only two species passing from the lower three to the two highest zones. There is not, however, such a clearly marked line of separation; the fauna of the *S. binodosus* zone seems from the tabulated species to be linked as closely with the higher as with the lower zones, for it contains sixteen species, of which number ten appear to be restricted to the zone and three range both up and down, while one passes downward only and two range upward. This result, however, is deceptive, because the Emscher is so poor in Echinoderms that only six species have been recorded from it, and only eight have been found in the *Marsupites* zone. If these zones were as productive in Germany as they are in England and France it

is probable that the number of species ranging from them to the equivalent of the *Offaster pilula* zone would be very much larger.

In the Franco-Belgian region a much greater number of Echinoderms has been obtained from the corresponding series of beds. The following table has been compiled chiefly from the separate lists given by M. de Grossouvre in the work already mentioned, but the Belgian species have been corrected in accordance with Mr. Lambert's recent revision of them, as published in the Mém. Mus. Roy. Belg. for 1911. I have not, however, included all his new species. The Belgian occurrences are indicated by the letter B., and those in France by the letter F.; these latter include the records from Touraine and the Cotentin as well as the Paris Basin :—

TABLE V.

ECHINODERMATA OF THE UPPER CHALK IN THE NORTH OF FRANCE AND BELGIUM.

SPECIES.	Zone of *M. decipiens*.	Zone of *M. coranguinum*.	Zone of *Marsupites*.	Zone of *O. pilula* and *A. granulatus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Cidaris hirudo, Sorig.	x	x	x	x	x	x
C. subhirudo, Cott.	-	-	-	-	x	x
C. pseudohirudo, Cott.	-	-	-	-	-	x B.
C. sceptrifera, Mant.	x	x	x	x	x	x
C. clavigera, Koenig	x	x	x	-	x	x
C. Merceyi, Cott.	x	-	-	-	-	-
C. periata, Sorig	x	-	-	-	-	-
C. perornata, Forbes	x	x	-	-	-	-
C. subvesiculosa, d'Orb.	x	x	-	-	-	-
C. serrifera, Forbes	x	-	-	-	-	-
C. serrata, Desor	-	-	-	x	x	x B.
C. turonensis, Gauthier	-	x	x	-	-	-
C. Faujasi, Desor	-	-	-	-	-	x B.
C. Hardouini, Desor	-	-	-	-	-	B.
C. lingualis, Desor (*Porocidaris*)	-	-	-	-	-	B.
Cyphosoma radiatum, Sorig	x	x	-	x	x	x B.
C. granulosum, Goldf.	-	x	-	-	-	x
C. corollare, Agas.	-	x	-	-	-	B.
C. magnificum, Cott.	-	x	x	-	-	-
C. Koenigi, Mant.	-	x	x	x	B.	-
C. Delaunayi, Cott.	-	-	x	-	-	-
C. Corneti, Cott.	-	-	-	-	-	B.
C. elongatum, Cott.	-	-	-	x	x	x
C. remus, Cott.	-	x	-	-	-	-
C. spathuliferum, Forbes	-	-	-	-	-	B.
Salenia incrustata, Cott.	-	x	-	x	x	-
S. Bourgeoisi, Cott.	-	x	x	-	-	-
S. geometrica, Ag.	-	x	x	-	-	-
S. anthophora, Müller	-	-	-	B.	B.	-
S. Janeti, Cott.	-	-	-	-	-	x
S. Bonissenti, Cott.	-	-	-	-	-	x
S. Heberti, Cott.	-	-	-	-	x	-
S. maestrichtensis, Schlüter	-	-	-	-	-	x B.
Peltastes heliophorus, Cott.	-	-	-	-	-	x B.

Species.	Zone of *M. decipiens*.	Zone of *M. coranguinum*.	Zone of *Marsupites*.	Zone of *O. pilula* and *A. granulatus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Pyrina Bourgeoisi, Cott.	-	-	x	-	-	-
P. ovulum, Lam.	-	-	x	-	-	-
Nucleolites analis, Ag.	-	-	-	-	-	F., B.
N. minimus, Ag.	-	-	x	-	-	-
N. coravium, Ag.	-	-	-	-	-	F., B.
Echinobrissus Guillieri, Cott.	x	-	-	-	-	-
Catopygus elongatus, Desor	-	-	x	-	-	B.
C. fenestratus, Ag.	-	-	-	-	B.	B.
Oolopygus Orbigmyi, Cott.	-	-	-	-	-	x
O. pyriformis, Ag.	-	-	-	-	B.	B.
Trematopygus oblongus, Desor	-		x		-	-
Hemiaster nasutulus, Sorig	x	-	-	-	-	-
H. nucleus, Desor	x	-	-	-	-	-
H. ligeriensis, d'Orb.	-	-	x	-	-	-
H. angustipneustes, Desor	-	x	x	-	-	-
H. prunella, Lam.	-	-	-	-	-	F., B.
H. Neustriæ, Desor	-	-	-	-	-	F.
Linthia spiennesensis, Schlüter	-	-	-	-	-	B.
Cassidulus lapiscancri, Lam.	-	-	-	-	-	F., B.
C. elongatus, d'Orb.	-	-	-	-	-	B.
C. Peroni, Gautier	x	-	-	-	-	-
Clypeolampas ovum, Ag.	-	-	-	-	-	B.
Heteropneustes tenuiporus, Cott.	-	-	x	-	-	-
Caratomus avellana, Dubois	-	-	-	-	-	F., B.
C. ocellatus, Cott.	-	-	-	-	-	B.
C. hemisphericus	-	-	-	-	-	B.
C. peltiformis, Wahl.	-	-	-	-	-	B.
C. sulcatoradiatus, Desor	-	-	-	-	B.	B.
Hemipneustes ocellatus, Cott.	-	-	-	-	-	B.
H. striatoradiatus, d'Orb.	-	-	-	-	-	B.
Rhynchopygus Marmini, d'Orb.	-	-	-	-	-	F., B.
Faujasia Faujasi, d'Orb.	-	-	-	-	-	B.
F. Delaunayi, d'Orb.	-	x	-	-	-	-
Peromaster Cotteaui, Gauthier	-	-	-	-	x	-
Cardiaster granulosus, Goldf.	x	x	-	x	B.	F., B.
C. Heberti, Cott. (=*maximus*, Schl.).	-	-	-	-	-	F., B.
Plesiaster bucardium, Goldf.	-	-	-	-	-	B.
Galerites albogalerus, Klein	-	x	x	x	x	-
G. circularis, Buc.	-	x	x	-	-	-
G. sulcatoradiatus, Goldf.	-	-	-	-	-	B.
Echinocorys scutatus, var. *gibba*	x	x	-	-	-	B.
E. scutatus, var. *striata*	-	x	x	x	x	x B.
E. scutatus, var. *conica*	-	x	x	x	x	x B.
E. scutatus, var. *meudonensis*	-	-	-	-	-	x B.
E. orbis, Arnaud	-	-	-	-	-	x B.
Holaster placenta, Ag.	x	-	-	-	-	-
Offaster pilula, Lam.	-	-	x	x	x	x B.
O. Gauthieri, Lamb.	-	-	-	-	-	x
Orthopsis miliaris, d'Arch.	-	-	x	-	-	-
Holectypus turonensis, Desor	-	-	x	-	-	-
Epiaster brevis, Schlüter	x	-	-	-	-	-
E. gibbus, Schlüter	-	x	x	-	-	-
Micraster decipiens, Bayle	x	-	-	-	-	-

Species.	Zone of *M. deciperis*.	Zone of *M. coranguinum*.	Zone of *Marsupites*.	Zone of *O. pilula* and *A. grandatus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Micraster turonensis, Bayle	-	x	-	-	-	-
M. senonensis, Lamb.	x	x	-	-	-	-
M. senonensis, var. *belgica*, Lamb.	-	-	-	B.	-	-
M. icaunensis, Lamb.	x	-	-	-	-	-
M. Cayeuxi, Parent	x	x	-	-	-	-
M. coranguinum, Leske	-	x	x	B.	B.	-
M. gibbus, Lam., var. *fastigatus*	-	-	-	x	-	-
M. gibbus, Lam., var. *Stolleyi*	-	-	-	-	B.	B.
M. Brongniarti, Hébert	-	-	-	-	-	F., B.
M. Schroderi, Stolley	-	-	-	-	x B.	F., B.
M. regularis, Arnaud	-	-	-	-	x	F.
M. ciplyensis, Schlüter	-	-	-	-	-	B.
Leucaster remensis, Gauthier	-	-	-	-	x	-
Marsupites testudinarius, Schloth.	-	-	x	-	-	-
Uintacrinus westfalicus, Schlüter	-	-	x	-	-	-
Bourgeticrinus ellipticus, Müll.	x	x	x	x	x	-

In considering this table, if in the first place we leave the *Offaster* zone out of account we find that the three lower zones have yielded forty-eight species and that the two higher zones contain no fewer than fifty-six species. Of this large number only ten species and varieties are common to the two assemblages, which are thus very different, though, as might be expected, they are not so entirely distinct as those of the more highly organized Cephalopoda.

The line of division between the two stages is not, however, so clearly indicated by the Echinoderms, for the fauna of the *Offaster* zone seems to form a complete passage from the one to the other. This zone has yielded fifteen species, of which ten range both up and down, one ranges downward only, three range up but not down, and one is restricted to the zone. The fact is that the tabulated number of occurrences is hardly sufficient to give a reliable result, and we can only infer that the zone might be placed in either stage.

In passing to the South of France we come to a different area of deposition, inhabited by an assemblage of Echinoderms which differed considerably from that of the Anglo-Parisian basin. Some of the northern species do occur in it, but there are a large number of others. From the lists given by M. de Grossouvre, in the work already mentioned, I have compiled a table of the distribution of species in the Aquitanian and Pyrenean areas, in order to ascertain what evidence they afford. This list includes no fewer than one hundred species, and yet is probably not quite complete; the greater number (sixty-three species) occur in the two higher zones and only ten of these range down into the three lower zones. The equivalent of the *Offaster* zone has yielded twenty-four species, and of these ten range both upward and downward, three range down only, and six pass up, while five are restricted. Here again, therefore, the existence of two different faunas and consequently of two distinct

stages is very apparent, but there is a transition from one Echinoderm fauna to the other, and the zone might be placed in either stage.

Lastly, Table VI shows the distribution of the Echinoids and Crinoids through the same zones in England, and in compiling this I have received special assistance from Mr. A. W. Rowe, who has kindly sent me notes regarding the identification and range of all the species, so that this list is more correct than any that has previously been published.

In comparing this with the preceding lists it will be noticed that the number of species is less and that the proportion of them which ranges from the lower to the higher zones is greater. Both these peculiarities are doubtless owing to the fact that in England there is little variation in the lithological character of the Upper Chalk, the whole of it being a deep-water facies of the formation deposited under conditions which did not change greatly from beginning to end. There was, therefore, no sudden or rapid extinction of species, only the increasing rarity of some and the occasional introduction of new forms.

In spite of these conditions there are many species which do not range from the lower to the higher zones. The total number of species and varieties enumerated is fifty-one, and of these forty-four occur in the lower four zones and twenty-five in the two higher zones, nineteen species being common to the two assemblages. This is less than half of the larger fauna, so that there is still a considerable difference between them. The zone of *O. pilula* has yielded twenty-seven species, of which seventeen range both up and down, only two have an exclusively upward range, while eight do not range higher; it is therefore more closely connected with the lower than the higher zones.

TABLE VI.

ECHINODERMS IN ENGLAND.

SPECIES.	Zone of *M. cortestudinarium*.	Zone of *M. coranguinum*.	Zone of *Marsupites*.	Zone of *O. pilula* and *A. granulatus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Cidaris hirudo, Sorig	x	x	x	x	x	x
C. sceptrifera, Mant.	x	x	x	x	-	-
C. clavigera, Koenig	x	x	x	-	-	-
C. perornata, Forbes	x	x	x	x	-	-
C. subvesiculosa, d'Orb.	x	x	x	x	x	x
C. Merceyi, Cotteau	x	x	-	-	-	-
C. serrifera, Forbes	x	x	-	-	-	-
C. serrata, Desor	-	-	-	-	-	x
C. pleracantha, Ag.	-	x	-	x	x	x
Cyphosoma Koenigi, Mant.	x	x	x	x	-	x
C. corollare, Ag.	-	x	x	x	x	x
C. granulosum, Goldf.	x	-	-	-	-	-
C. magnificum, Cott.	-	-	-	x	x	x
C. elongatum, Cott.	-	-	x	-	-	-
C. radiatum, Sorig	x	x	x ?	-	-	-
C. spatuliferum, Forbes	x	x	x	x	-	-

Species.	Zone of *M. cortestudinarium.*	Zone of *M. coranguinum*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Salenia granulosa, Forbes	x	x	x	x	x	x
S. geometrica, Ag.	-	-	x	x	x	x
S. magnifica, Wright	-	-	-	-	x	x
Zeuglopleurus Rowei, Gregory	-	-	x	-	-	-
Helicodiadema fragile, Wilt.	-	x	x	x	x	x
Echinocorys scutatus, Leske (*ovata*)	-	x	x	x	x	x
E. scutatus, a gibbous form	-	-	x	x	-	-
E. scutatus, var. *gibba*, Lam.	x	-	-	-	x	-
E. scutatus, var. *depressa*, Bryd.	-	x	x	x	-	-
E. scutatus, var. *pyramidata*, Bryd.	-	-	x	x	-	-
E. scutatus, var. *subconica*, Bryd.	-	-	-	-	-	x
Galerites albogalerus, Leske	x	x	x	x	-	x
G. albogalerus, var. *globulus*, Desor	-	x	x	-	-	-
Cardiaster ananchytis, Goldf.	-	x	x	x	-	x
C. Cotteauanus, Schlüter	x	-	-	-	-	-
Offaster pilula, Lam. (type)	-	-	x	x	x	x
O. pilula (dwarf var.)	-	-	-	-	x	x
Holaster planus, Mant.	x	-	-	-	-	-
H. placenta, Ag.	x	x	x	x	-	-
Micraster cortestudinarium, Goldf.	x	-	-	-	-	-
M. præcursor, Rowe	x	x	-	-	-	-
M. coranguinum, Leske	-	x	x	x	x	-
M. glyphus, Cott.	-	-	-	-	x	x
Epiaster gibbus, Lam.	x	x	x	-	-	x
Infulaster excentricus, Bosc.	x	x	x	-	-	-
I. rostratus, Forbes	-	x	x	x	x	-
Hemiaster minimus, Ag.	x	x	x	x	x	x
Marsupites testudinarius, Schloth.	-	-	x	-	-	-
Uintacrinus westfalicus, Schlüter	-	-	x	-	-	-
Pentacrinus Bronni, Hagenow	-	-	-	-	-	x
P. Agassizi, Hagenow	x	-	-	-	-	-
Isocrinus Kloedeni, Hagenow	-	x	x	x	-	-
Bourgeticrinus ellipticus, Müller	x	x	x	x	x	x
Ophiura serrata, Römer	-	x	x	x	-	-
Roveacrinus communis, Douglas	x	x	x	x	-	x

Another group of fossils which furnishes useful evidence of the distinctness of the two faunas is the genus *Inoceramus*. This was studied by Schlüter in Germany in 1876,[1] and a tabular view of this zonal distribution in that country is given at the end of his monograph. Recently the genus has been more thoroughly investigated, so far as the British species are concerned, by Mr. H. Woods, whose excellent monograph will henceforward be the chief book of reference for the European species generally.

The species which occur in France, Germany, and other countries now require re-examination in the light of Mr. Woods' researches and studies of the various type-specimens, but by the aid of some notes on foreign forms in Mr. Woods' monograph, I have been able to compile a list of those which occur in the Paris Basin.

[1] *Palæontographica*, Bd. xxiv, 1876–7.

The following tables, showing the zonal distribution of the species of *Inoceramí*, have thus been prepared from the sources above mentioned, that for North Germany being taken from Schlüter, with some corrections and modifications :—

TABLE VII.

Inoceramí in the Upper Chalk of England.

Species.	Zone of *M. cortestudinarium*.	Zone of *M. coranguinum*.	Zone of *Marsupites*.	Zone of *O. pilula*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Inoceramus Lamarcki, Park. (type) (= *I. Brongniarti*, Mant.)	x	x	-	-	-	-
I. Lamarcki, var. *Cuvieri*, Sow.	x	x	-	-	-	-
I. Lamarcki, var. *Websteri*, Mant.	x	-	-	-	-	-
I. Lamarcki, var. *undulatus*, Mant.	x	-	-	-	-	-
I. cordiformis, Sow.	x	x	x	-	-	-
I. involutus, Sow.	x	x	-	-	-	-
I. inconstans, Woods	x	x	x	x	x	x
I. inconstans, var. *striatus*, Mant.	?	x	-	-	-	-
I. inconstans, var. *sarumensis*, Woods	-	-	-	x	-	-
I. digitatus, Sow.	-	x	-	-	-	-
I. undulato-plicatus, Römer	-	x	-	-	-	-
I. undulato-plicatus, var. *digitatus*, Sch.	-	x	-	x	-	-
I. cardissoides, Goldf.	-	-	?	x	-	-
I. subcardissoides, Schlüter	-	?	-	-	-	-
I. pinniformis, Will.	-	-	-	x	-	-
I. balticus, Bohm	-	-	x	x	x	x
I. lingua, Goldf.	-	-	x	x	?	x
I. lobatus, Goldf.	-	-	x	x	-	-
I. tuberculatus, Woods	-	-	-	x	-	-

TABLE VIII.

Inoceramí in the Upper Chalk of North Germany.

Species.	*Cuvieri* zone.	The *Emscher*.	Zone of *Marsupites*.	Zone of *S. binodosus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*.
Inoceramus Lamarcki, Park. (= *Brongniarti*, Schlüter, etc.)	x	-	-	-	-	-
I. Lamarcki, var. *Cuvieri*, Sow.	x	x	-	-	-	-
I. involutus, Sow.	-	x	-	-	-	-
I. involutus, var. *exogyroides*, Meek	-	x	-	-	-	-
I. involutus, var. *umbonatus*, Meek	-	x	-	-	-	-
I. digitatus, Sow.	-	x	-	-	-	-
I. subcardissoides, Schlüter	-	x	-	-	-	-
I. undulo-plicatus, Schlüter	-	x	-	-	-	-
I. radians, Schlüter	-	x	-	-	-	-
I. subquadratus, Schlüter	-	x	-	-	-	-
I. gibbosus, Schlüter	-	x	-	-	-	-
I. cardissoides, Goldf.	-	?	x	-	-	-
I. cancellatus, Goldf.	-	-	x	x	-	-
I. balticus, Bohm (= *Crippsi*, auct.)	-	-	x	x	x	x
I. lingua, Goldf.	-	-	x	x	-	-
I. lobatus, Goldf.	-	-	x	x	-	-

TABLE IX.

Inoceramı in the Upper Chalk of the Paris Basin.

Species.	Zone of *M. decipiens*.	Zone of *M. coranguinum*.	Zone of *Marsupites*.	Zone of *O. pilula* and *A. grandiatus*.	Zone of *A. quadratus*.	Zone of *B. mucronata*
Inoceramus Lamarcki, Park. (type)	x	x	-	-	-	-
I. Lamarcki, var. *Cuvieri*, Sow.	x	x	-	-	-	-
I. Lamarcki, var. *Mantelli*, de Mercey	x	x	-	-	-	-
I. Lamarcki, var. *undulatus*, Sow.	x	-	-	-	-	-
I. inconstans, Woods (= *Brongniarti*).	x	-	-	-	-	-
I. involutus, Sow.	x	x	-	-	-	-
I. digitatus, Sow.	-	x	-	-	-	-
I. lezennensis, Decocq	-	x	-	-	-	-
I. inæquivalvis, Schlüter	x	-	-	-	-	-
I. unduloplicatus, Röm.	-	x	-	-	-	-
I. subcardissoides, Schlüter	-	x	-	-	-	-
I. balticus (= *Crippsi*, auct.)	-	-	-	-	x	x
I. lingua, Goldf.	-	-	?	-	-	-

From these lists it will be seen that the English list is the most complete, and that the evidence of the *Inocerami* accords entirely with that of the Cephalopoda. The zone of *Offaster pilula* in England has yielded nine species, of which five, and probably six, range downward, while only three of them range upward. In Germany the same zone has yielded four species, all of which range down into the *Marsupites* zone and only one (*balticus*) passes up into the higher zones.

Inferences.

Reviewing the results which have been obtained from the tabulated distribution of Cephalopoda, Echinoderms, and *Inocerami* in the Upper Chalk, we arrive at the following conclusions:—

1. That the Upper Chalk, with its equivalent in France and Germany, contains two distinct assemblages or faunas, and consequently that it comprises two stages as distinct from one another as are the Albian, Cenomanian, and Turonian.

2. That the evidence of the Cephalopoda fixes the line of division between the zones of *Offaster pilula* and *Actinocamax quadratus*.

3. That the distribution of *Inocerami* in all three countries leads to the same conclusion as that of the Cephalopoda.

4. That the evidence of the Echinoderms is less definite, because the assemblage found in the *O. pilula* zone is everywhere a passage fauna with many species that range both up and down.

The exact position of the boundary-plane between the two stages is of course a mere matter of detail. The important point, which is so obvious from an inspection of the preceding tables, is the recognition of the fact that our Upper Chalk is not a single stage comparable with the Middle Chalk or Turonian, but comprises two such stages for which names must be adopted.

With regard to the plane of division between them, the weight of evidence indicates that it should be drawn at the top of the zone of *Offaster pilula* and *Scaphites binodosus*. This line seems to be clear enough in Germany, but has not yet been accurately determined in England or France.

Nomenclature.

Having demonstrated the existence of two different faunas, and consequently of two different stages, in what we have hitherto been accustomed to call the Upper Chalk, it becomes necessary to consider by what names they should be called. The old-fashioned names Lower Middle and Upper Chalk may still be used for divisions which can be shown on geological maps, because they have usually well-marked lithological boundaries, but we cannot continue to employ them as stage-names, since the Chalk is really divisible into four stages, not three as was formerly supposed.

There can be little doubt that we must adopt the French method of nomenclature, and it will also be convenient to employ the actual French names for these stages as far as possible, because these names are in general use on the Continent. Unfortunately, however, the French geologists are not yet agreed on the question of simplifying their nomenclature and making it accord with the stratigraphical value of their divisions.

The French terminology originated with d'Orbigny in 1843, and at first he only recognized two divisions or stages in the Chalk, giving these the names of *Turonien* and *Sénonien*. Subsequently he became aware that his Turonien included two distinct faunas and also that there was another fauna above his Sénonien in Denmark. Consequently in 1852 he established four stages under the names of *Cénomanien*, *Turonien*, *Sénonien*, and *Danien*. These names have been in use ever since that date, and the definitions of them given by d'Orbigny in his *Géologie Stratigraphique* of 1852 show that the first three correspond very closely with our Lower, Middle, and Upper Chalk.

As time went on, however, French geologists found that the Senonian was divisible into two or more parts, which they regarded as stages or sub-stages. Thus the Senonian of the Paris Basin was divided by Lambert in 1876 into Lower and Upper divisions, while that of Aquitaine was divided by Coquand into four parts, to which he gave the names of *Coniacien*, *Santonien*, *Campanien*, and *Dordonien*.[1]

In 1879 de Mercey pointed out that there were really only two separate stages in the Senonian of d'Orbigny, but that these ought to be recognized and that one of them should receive a new name while Senonian was retained for the other; just as d'Orbigny himself had given a new name to part of his original Turonian, but retained that name for a restricted Turonian. De Mercey advocated the retention of the name Senonian for the upper part and the adoption of Coquand's name Santonian for the lower part.[2]

The correlation of the successive zones was not, however, fully established in 1879. Coquand's stages were really sub-stages, but they

[1] Coquand, Bull. Soc. géol. France, ser. II, t. xiv, p. 746, 1857.
[2] Bull. Soc. géol. France, ser. III, t. vii, p. 355, 1879.

were definite stratigraphical units, and de Mercey was wrong in supposing that the *Coniacien* had no separate existence. The *Santonien* was not therefore the equivalent of the whole "Sénonien Inférieur" as he supposed. Moreover, French geologists were so accustomed to the use of the name Senonian in its wider and more comprehensive application that the idea of its restriction to a portion of the original stage did not commend itself to them. Hence a complicated system of stages and sub-stages was adopted, which included an unnecessary number of names and could not possibly be used with advantage in any other country. The following table shows the divisions recognized by de Grossouvre in 1901 :—[1]

Stages.	Sub-stages.	Assises.
Danien		
Sénonien	Campanien	Supérieur.
		Inférieur.
	Corbiérien	Santonien.
		Coniacien.
Turonien	Angoumien	
	Saumurien	
Cénomanian . .	(not divided).	

It is obvious that this scheme is illogical; the Corbiérien and Campanien have the same palæontological and stratigraphical value as the Turonian, and consequently the retention of a comprehensive Senonian can only produce confusion and misapprehension. This seems to have been perceived by de Lapparent, for in the latest edition of his *Traité de Géologie* he remarks (p. 1883) that "The old Sénonien of d'Orbigny really includes two very distinct faunas of Cephalopoda, *Mortoniceras* and *Placenticeras* prevailing in the one which is the fauna of the Emscher marls of Westphalia. The other fauna, in which *Pachydiscus* and *Baculites* are conspicuous, is that of the Chalk of Haldem and Lemberg and of the beds near Tercis. The beds which contain it form the Aturien stage, from the Adour on the banks of which this division is well developed".

De Lapparent therefore divides his Upper Cretaceous Series into six stages, for which he adopts the names Cénomanien, Turonien, Emschérien, Aturien, Danien, and Montien, thus excluding the Albien and including the Montien, which others regard as the base of the Eocene Series. The stages with which we are concerned he subdivides in the following manner:—

Stages.	Sub-stages.	Zones.
Aturien	Maestrichtien	Calcaire à *Baculites*.
	Campanien	Craie de Meudon.
		Craie de Reims.
Emschérien	Santonien	Craie à *Marsupites*.
		Craie à *M. coranguinum*.
	Coniacien	Craie à *N. cortestudinarium*.

From this it is evident that de Lapparent wished to abandon the term Senonian altogether instead of adopting the view advocated by

[1] "Recherches sur la Craie Supérieur": Mém. Carte Dét. de la France, fasc. ii, table after p. 700.

de Mercey; further, that he proposed two new stage-names when he might have adopted those used by de Grossouvre. On the other hand, it seems to me that de Mercey was right in principle and that he was quite justified in saying—"L'équité scientifique exige que les dénominations des étages de d'Orbigny subsistent dans le nomenclature, quels que soient les changements apportés dans la délimitation des étages, ou bien les démembrements opérés à leur dépens."

I am therefore strongly of opinion that the name Senonian should be used for one of these stages, and the only question is to which of them should it be applied. The name is taken from the tribe of the Senones who inhabited the country round Sens, and so far as this typical area is concerned it might be used equally well for either division, since the beds of the Lower Senonian crop out to the south-east of Sens and those of the Upper Senonian to the north-west.

We need therefore only consider to which stage the name can be most usefully and conveniently applied. Now de Grossouvre has shown that the 'Maestrichtien' is not a sub-stage, but only a part of the zone of *Pachydiscus neubergicus*, which is elsewhere included in the Campanian; in the same way its equivalent in Aquitaine (the Dordonien) is shown to be merely part of the Campanian.[1] Consequently he adopts the name *Campanian* (derived from the 'champagne' of the Charentes) to denominate the stage for which de Lapparent introduces the new name of *Aturian*. Campanian has the priority, and is now generally recognized by French geologists as a good name for this division of the Upper Chalk. There is, therefore, no need for Aturian, which should be dropped as a synonym.

On the other hand, all the names proposed for the 'Sénonien Inferieur' are open to objection. The application of Santonian to the whole stage is untenable, because the real and original Santonian was only a part of it, and Coquand was right in so regarding it. The name *Corbiérien* has not found favour in France because it is taken from a locality, Corbiéres in the Pyrenees, where the beds differ from those of the Anglo-Parisian Basin, both in their fauna and their lithological characters. '*Emschérien*' is open to the same objection, the Emscher marls being a local facies and their fauna a poor one, especially in Echinoderms, so that they do not form a suitable exemplar or type for reference.

These considerations make it clear that if the name Senonian is to be used at all it should be applied to the lower part of d'Orbigny's division, that of Campanian being adopted for the higher one. Further, there is not the slightest occasion for the use of sub-stages; a primary division of the series into stages and a subdivision of these stages into zones is all that is necessary, any kind of intermediate term is both cumbersome and useless.

In its complete development the Chalk of Northern Europe appears to be divisible into five stages, though the Danian is of smaller

[1] In both districts, however, it forms the highest portion of his zone of *P. neubergicus*, and is characterized by the presence of *Sphenodiscus Ubaghsi* and a special set of Echinoderms, so that it seems to be separable as a distinct zone.

thickness and altogether of smaller importance than the rest. The following table sets forth the names which I would adopt for these stages, and the zones which they comprise:—

Stages.	Zones.
Danian	*Nautilus danicus.*
Campanian	*Belemnitella mucronata.* *Actinocamax quadratus.*
Senonian	*Offaster pilula.* *Marsupites.* *Micraster coranguinum.* *M. decipiens.* *Holaster planus.*
Turonian	*Terebratulina lata.* *Rhynchonella Cuvieri.*
Cenomanian	*Holaster subglobosus.* *Schloenbachia varians.*

V.—Note on the Chalk Rock in North Kent.

By G. E. Dibley, F.G.S.

In the early spring of 1910, while collecting in the Chalk quarry at Borstal,[1] I found in a loose piece of chalk an impression of a small Gasteropod shell which probably belongs to the genus *Lampusia*. Shortly afterwards, while at the Borstal Manor Quarry, a workman brought me another small Gasteropod, which has since been identified as *Turbo geinitzi*, Woods. Both specimens were preserved as casts, showing part of the external ornament from near the apex to the basal whorl. Part of the zone of *Holaster planus* is exposed in the quarry, but the locality is not included in my previous list of exposures in the neighbourhood. The occurrence of these Gasteropods at such an horizon was almost conclusive evidence of the presence of the *Reussianum* fauna, so I again visited the quarry, in company with my wife, with a view to discovering the exact position at which these fossils occurred.

The lithological character of a certain bed of Chalk at Borstal is exactly the same as that on the other side of the Medway, being exposed in Messrs. Martin & Earl's quarry at Wickham (No. 2)[2] and at Messrs. Trechmann's quarry at Cuxton (No. 4). A small block from this bed, about the size of a cubic foot, would be found to contain irregular patches deeply iron-stained and of a nodular and fibrous character, the remainder being soft and gritty. I had for some time been familiar with its distinctive lithological features, but until that time had never succeeded in obtaining any fossils from it. A more detailed search at Wickham yielded a small indeterminable Gasteropod cast, and a specimen of *Dentalium turoniense*, Woods.

In the spring of this year we again visited the Borstal Quarry, which had been unworked since December, and during five hours' search came across the rich molluscan fauna that characterizes the 'Chalk Rock'. This was in the bed of Chalk, about 5 feet in

[1] Proc. Geol. Assoc., vol. xvi, p. 484, 1900.
[2] These numbers refer to the list of exposures in (1).

thickness, at the floor of the pit. The upper limit of the bed passes imperceptibly into the *Holaster planus* Chalk.

At Blue Bell Hill this fauna can be collected from the Chalk, one hundred yards from the summit (about 750 feet O.D.), at the sides of the path immediately opposite the church, between the school and the Windmill Inn. Most probably this bed crops out again in the large pit at the top of Blue Bell Hill (No. 10), but the face of the Chalk is too precipitous to allow of an examination.

The following is the list of fossils found in this bed. With the exception of the Echinoids and Brachiopods, most are preserved as casts, and on the whole can be determined only by the taking of gutta-percha moulds.

Heteroceras reussianum (Orb.); *Baculites bohemicus*, Fritsch; *Ptychoceras Smithi* (Woods); *Scaphites geinitzi*; *Hamites* sp. (?), Orb.; *Prionocyclus neptuni* (Geinitz); *Dentalium turoniense*, Woods; *Avellana* sp., cf. *humbolti*, Miller; *Trochus schluteri*, Woods; *Trochus berocscirense*, Woods; *Lampusia* (?) sp.; *Turbo geinitzi*, Woods; *Solariella gemmata* (Sowerby); *Trapezium trapezoidale* (Römer); *Septifer lineatus* (Sowerby); *Inoceramus costellatus*, Woods; *Inoceramus inconstans*, Woods; *Limatula* sp.; *Spondylus spinosus* (Sowerby); *Liothyrina semiglobosa* (Sowerby); *Rhynchonella limbata* (Schlotheim); *Rhynchonella plicatilis* (Sowerby); *Holaster planus*, Mantell; *Micraster præcursor*, Rowe; *Micraster leskei*, Desmoulins; *Parasmilia* sp.; *Trochocyathus* sp.; Sponges (abundant).

Mr. H. Woods[1] proposed the term 'zone of *Heteroceras reussianum*' for this assemblage, and remarked that it was not always characterized by its peculiar lithology. He mentioned Twyford, near Winchester, as a locality where the horizon can be recognized only by its fossils. In the present district also it is patent that since the Chalk Rock (*sensu str.*) is absent, the palæontological term is to be preferred for denoting this horizon. A more general use of this term as an index to the horizon is highly desirable, because, as Mr. Woods has already pointed out, the term 'Chalk Rock' is both inadequate and in some cases ambiguous. Owing to this bed being less conspicuous in its lithology than usual, it is highly probable that a detailed examination of the Chalk at this part of the *Holaster planus* zone may throw considerable light on the persistence of this zone.

We again visited the Borstal Quarry, recently, accompanied by Mr. P. Dollman, and during seven hours' work succeeded in revealing very important features after clearing a few yards of the surface. About ten feet above the floor a band of deeply iron-stained, nodular chalk is seen to be persistent throughout the quarry; these nodules are very hard and contain beautiful casts of Sponges, Lamellibranchs, Gasteropods, and Cephalopods. Immediately below the nodular band the chalk is decidedly soft, friable and somewhat gritty; but portions of the mass are very hard and not easily distinguishable by the eye from the surrounding matrix. I have obtained three beautiful examples of *Scaphites geinitzi* from this horizon, and we found *Micraster leskei* more frequently here than in any other part of the quarry.

The day previous to the visit to Borstal, we spent several hours at

[1] Q.J.G.S., vol. lii, p. 70, 1896.

Blue Bell Hill, and knowing the position of the very hard band[1] and that only a depth of about 12 feet of chalk have been removed at Borstal, explorations were made at the side of the path *downwards* as far as the West Kent Waterworks boundary-stone. As on the former visit, we obtained the characteristic fauna, including a fine cast of *Prionocyclus neptuni* (Geinitz), and also proved that a considerable thickness has to be allowed for this sub-zone.

Following up my theory on returning home, I visited Kenley (in the Caterham Valley) two evenings afterwards, and went to the Rose and Crown Quarry (32) accompanied by a friend, but finding the face of the quarry too precipitous for working we crossed the railway at the bridge and made our way about the top of the railway cutting to the commencement of the viaduct. Here we were obstructed by a thickness of nodular chalk ('hill-wash') and found that further progress was impossible. We retraced our steps by the fence which marks the railway company's boundary till we reached a spot which, by the dip of the beds, I considered to be the horizon at which this sub-zone should appear. After removing the superincumbent drift, we found remains of *Dentalium*, *Scaphites*, Gasteropod casts, and sponges in *hard white chalk* corresponding to the matrix at Borstal and Blue Bell Hill. I think that the 'finds' at this spot amply prove the truth of my previous remark that the *Reussianum* zone will be found to be persistent and must not be looked for on lithological grounds only, but on palæontological evidence.

In conclusion, I may add that I am deeply indebted to my friends Messrs. Chatwin and Withers for the great interest they have displayed in this matter and for assistance most cheerfully given.

Note. Since visiting Kenley I learn that Messrs. T. H. Withers, F.G.S., and C. P. Chatwin had already discovered this fauna in fallen blocks at the Rose and Crown Quarry and at Whyteleafe. Similar corroboration may be expected from other observers in the Chalk areas where outcrops or workings in the *Holaster planus* zone occur.

A subsequent visit to Amberley in Sussex has proved fruitful in revealing the existence of the *Reussianum* zone in the quarry outside the station.

REVIEWS.

I.—Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1911. pp. iv, 90, with 4 text-illustrations. London: printed for H.M. Stationery Office, 1912. Price 1*s*.

THIS memoir contains much of interest and importance concerning the work of the Geological Survey in various parts of Great Britain.

In the Denbighshire district work has been carried out among the Carboniferous rocks, the grouping of which in the original one-inch maps and in the memoir on the adjacent Flintshire district was

[1] The band exactly corresponding to the nodular band at Borstal has not yet been found in situ at Blue Bell Hill, but there is every reason to expect that its existence will be proved.

strongly opposed by Dr. Wheelton Hind and Mr. J. T. Stobbs (Geol. Mag. 1906). Their paper is mentioned in a footnote, but their advice does not appear to have been taken. No satisfactory evidence, however, is given for the continued classification of the strata termed Millstone Grit, nor of the Gwespyr Sandstone, etc. The red or purple marls overlying the Middle Coal-measures, and termed the Ruabon Marls, are estimated to attain a thickness of about 900 feet: of these the lower beds are worked for bricks and terra-cotta clay. The succeeding Coed-yr-allt group consists of sandstones and shales with *Spirorbis*-limestones; and the highest division, termed the Ebbistock Beds, is a thick series of red and purple sandstones with conglomeratic bands and much red marl.

In what is termed the Warwickshire district, which includes South Staffordshire, attention has been given to the Cambrian and Silurian rocks, and more particularly to the Coal-fields of South Staffordshire and North Warwickshire. In the last-named coal-field the succession is given as follows:—

Upper Red Marls and Sandstones. ('Permian' on old map.)
Upper Grey Measures. Halesowen Sandstone Series.
Lower Red Marls and Espley rocks.
Lower Grey Measures, in which alone workable coal-seams occur.

The Espley rocks are described as sometimes bright green in colour, and composed of angular chips of green shale, derived as scree material from the Cambrian Shales of Dosthill.

Breccia-beds or conglomerates with some pebbles, but mostly with angular fragments of limestone, are described as occurring above the upper part of the 'Permian' and below the Bunter pebble-beds; but there is at present considerable doubt about the grouping of these and some other Red rocks of pre-Triassic age.

In the London and South-Eastern district work has been carried on at Aylesbury and over the Chiltern Hills to Rickmansworth, and in the Bagshot areas about Ascot and Weybridge.

In Scotland the survey has been prosecuted in the West Highland district, on the gneiss and newer granites of Morvern and on the Tertiary igneous rocks of Mull; and in the North and Central Highland district among the metamorphic and associated igneous rocks of Ben Armine in East Sutherland and those of parts of Perth and Inverness. Revisions of the areas of coal-fields were made in the districts of Carluke, East Kilbride, and Douglas, and in those of Shotts and Fauldhouse. The crumpling in certain sandstones of the Millstone Grit is attributed to the decay of buried tree-trunks. In another area an illustration is given of certain 'wants' (or lack of continuity) in coal-seams adjacent to a fault; and the subject recalls to mind Dr. R. L. Jack's paper "On 'Wants' in Ironstone Seams" (Geol. Mag. 1871, p. 388).

In the record of palæontological work some interesting remarks are made on the forms of *Gryphæa* in the Lower Lias, a subject to which the late John Jones, of Gloucester, gave great attention and illustrated in quarto plates. Important records of Liassic and Oolitic fossils from Mull and from marine Upper Carboniferous beds in Central Scotland are also given. In the Appendix Dr. A. Strahan records

particulars of a highly interesting boring at Ebbsfleet near Ramsgate, where Carboniferous Limestone was reached below Coal-measures (103 feet thick), at a depth of 1,159 feet.

Another article, "On Diversions of the Bourne near Chertsey," is by Mr. C. N. Bromehead; a third is on "*Orthis proava*", by Dr. E. Matley; a fourth is entitled "Notes on the Upper Limestones of the Bathgate District", Edinburgh, by Mr. M. Macgregor; and a fifth is a "Note on Fossil Plants from Garallan Pit Sinking, ½ mile S.S.W. of Old Cumnock, Ayrshire", by Dr. R. Kidston.

II.—Cambrian Geology and Palæontology. No. 6: Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata. By C. D. Walcott. Smithsonian Miscellaneous Collections, vol. lvii, No. 6 (publication 2051), 1912.

SOME beautifully preserved Crustacea form the subject of the fourth preliminary paper on the collections from the Burgess Shale, Stephen formation, British Columbia. Altogether thirty-four new species are described, ten of which belong to the Branchiopoda, and represent seven new genera and four new families. Five new genera of Malacostraca are instituted, and fourteen species are referred to them. One new family of Trilobites—the Marrellidæ—is founded for the reception of four genera and six species, all new. Of the Merostomata a new order is described, and three genera and four species are placed in it.

The shale in which these important specimens are preserved is described as being smooth, compact, exceedingly fine-grained and siliceous; the fossils are irregularly distributed, occurring in layers, and they exhibit structures that are most surprising considering their age, thus indicating very little disturbance since the rock was deposited. In some specimens traces of the alimentary canal can be observed—in the new Trilobite genus *Marrella*, for example—and in one case, in *Burgessia*, it is seen to be large where the hepatic tubes join it, and to taper to its posterior end. In this same case the hepatic cæca are beautifully preserved and have the branched structure even better than in recent Copepods.

In structure the members of this fauna are not unlike recent Crustaceans of the same orders: the stalked eyes, the antennules, and antennæ are similar, while in the thoracic appendages there are no modifications that would indicate a more primitive form. Dr Walcott thinks it probable that in such of his new Branchiopod genera as *Opabinia* and *Burgessia* we see ancestral forms of the recent Polyartemidæ and Apodidæ, and that even in Cambrian times their great power of reproduction and their active movements enabled them to flourish "in the midst of active and powerful enemies". There is a remarkable similarity of structure in the antennæ, legs, and branchiæ of the Burgess Shale Trilobites, and those of Ordovician age, and with this new material the author now agrees with Burmeister and Bernard that the Trilobites are related more closely to the Branchiopods. The discovery of caudal rami in *Neolenus* corroborates Bernard's idea that the Trilobites came from the same

stock as *Apus*. We see the commencement of the Trilobite form in *Marrella*, an *Apus*-like Crustacean, but more highly developed, and with jointed legs and fewer segments. *Marrella*, with its leg-like endopodite and expanded gill-like epipodite, is very abundant in the Burgess Shale, and has a small, strong, sub-quadrangular carapace with two postero-lateral spines and sessile eyes.

The Cambrian Crustacean fauna seems to show that five main stems (Branchiopoda, Malacostraca, Ostracoda, Trilobita, and Merostomata) started in the early Cambrian, and that all had their beginning in pre-Cambrian (Lipalian) time. Dr. Walcott thinks that more work in the Lower Cambrian will bring to light a large and varied Crustacean fauna: the occurrence of *Beltina* in the pre-Cambrian of the Rocky Mountains certainly seems to support this.

In dealing with the descent of the Cambrian Crustaceans from a "theoretical ancestral stock" (correlated with the Apodidæ) the author assumes that the Branchiopoda came first, and from these three distinct branches were developed before or during the Cambrian. The Trilobites are thought to come directly from the Branchiopods, and descent is considered to go through the Aglaspina and Limulava to the Eurypterids, and thence to the Xiphosura. The Hymenocarina and the Ostracoda are the other two lines of descent from the Branchiopods. These views are regarded only as tentative, and Dr. Walcott hopes to make a more detailed study when further material is available. The eleven plates illustrating this paper are particularly fine.

No. 8 (publication 2076) of the same volume of Smithsonian publications is a paper by the same author on "The Sardinian Cambrian genus *Olenopsis* in America". Until now the stratigraphical position of this genus in relation to the *Olenellus* and *Paradoxides* faunas has been uncertain. In the present paper Dr. Walcott describes three new species (*O.* (*?*) *agnesensis*, *O. americanus*, and *O. roddyi*) which give the genus a definite horizon and an extensive geographical range in North America, the new localities being in Central Pennsylvania, Montana, Alberta, and British Columbia. The horizons are Lower Cambrian and the passage beds to the Middle Cambrian. From the evidence Dr. Walcott suggests that the genotype—*O. zoppii* (Meneghini)—occurs beneath the Middle Cambrian *Paradoxides* beds in Sardinia, and as regards generic relationships he thinks that both *Olenopsis* and *Paradoxides* are descended from the *Holmia* type of the Mesodonacidæ. There is one plate, and this contains, besides figures of the new species, several photographs of *O. zoppii* from the type locality for comparison.

III.—The Origin of Earthquakes. By Charles Davison, Sc.D., F.G.S. 8vo; pp. viii, 144, with 26 text-illustrations. Cambridge: at the University Press, 1912. Price 1*s.* net.

THIS is a companion volume to that on Rocks by Professor Cole, and gives a comprehensive view of what is known about the origin of Earthquakes in language clear and concise. The author's plan is to confine his attention to the phenomena essential to any

explanation of the origin of the disturbances. A study of their distribution shows that, while some earthquakes are more or less directly connected with volcanoes, active or dormant, others, including the more important and destructive, happen in districts remote from modern volcanic action. Destructive earthquakes occur on "the steeply sloping ocean-bed to the east of the Japanese empire. In the same way, the disastrous earthquakes of South America originate beneath the Pacific Ocean, in districts that are distant many miles from the volcanic vents of the Andean chain. The great earthquakes of India and Turkestan, again, occur in countries from which volcanic action is now entirely absent, but which lie on the steep sides of mountain ranges that are known to be of recent growth".

Earthquake shocks are of all degrees of intensity, from mere tremors to those which affect areas of nearly two million square miles, although, whether weak or strong, it is considered that, as a general rule, the centre of the disturbance is not more than a few miles below the surface.

In considering the folding and fracturing of the rocks forming the earth's crust, the author remarks that the folding would take place slowly, until it gave place to fracturing and faulting. Fractures would appear on the surfaces of folded rocks, and some earthquakes may be attributed to such causes; but it is regarded as more probable that they are caused by the abrupt and violent process of faulting. The author's principal object is "to show that the great majority of earthquakes are due to the intermittent growth of faults, that, when a displacement occurs at some depth, the friction generated by the sudden sliding of one huge rock-mass over and against the other must produce an intense jar in the solid crust around, a series of vibrations which, propagated outwards in all directions, gives rise at the surface to an earthquake shock; and that, in those somewhat rare cases in which the displacement is continued right up to the surface, the sudden spring of the displaced crust must complicate and increase the shock due to the grating of the sliding masses".

The phenomena observed in connexion with earthquakes, simple, twin and complex, in various parts of the world, the formation of fault-scarps, and other features, are duly described; and references are given to the leading publications on the subject.

IV.—Rocks and their Origins. By Grenville A. J. Cole, Professor of Geology in the Royal College of Science for Ireland. 8vo; pp. viii, 175, with 20 text-illustrations. Cambridge: at the University Press, 1912. Price 1*s.* net.

IN this little volume, issued as one of "The Cambridge Manuals of Science and Literature", the author deals with the method of formation of limestones; sandstones; clays, shales, and slates; igneous and metamorphic rocks. Some attention is given to the colours of the rocks, and their soils, and more to the varied forms of scenery to which they give rise: a subject treated in most of the illustrations, among which the quartzite cone of Croagh Patrick is an example. It is needless to say that the volume is clearly and

pleasantly written throughout; and the author contrives, in his limited space, to give information not only concerning the latest researches and views, but of the studies of the earlier workers among rocks, such as Cordier, Macculloch, Scrope, Ehrenberg, and Sorby. He remarks that "we are still far from discovering the primitive crust formed about a molten globe", and suggests that the "early sediments became frequently immersed in baths of molten matter, and that contact-metamorphism and admixture on a regional scale have produced in them the characters that have been attributed to a fundamental gneiss".

While the Pre-Cambrian and early Cambrian limestones may have been products of chemical precipitation, as they show no signs of organic agency, yet, as Rutley pointed out (1893), the features may be due to metamorphic influence, as in the case of the Carrara Marble. Attention is drawn to altered forms of massive limestone that have become dolomitic or phosphatic, and to the replacement of limestone by silica; here a few words might have been written on the changes into ironstone.

In treating of clays the author gives some account of Boulder-clay, remarking that "Swiss glaciers are now so limited that they are of very little use to us when we seek to explain the origin of boulder-clay"; and he appeals to the great continental glaciers of polar regions, giving also some personal observations on the minor glacial action in Spitzbergen.

The work is intended for those who are not specialists, and we may cordially commend it to junior students and general readers, while at the same time many a teacher will be glad of its helpful guidance.

V.—Geology and Physics.—The question of the depth of the zone of flow in the earth's crust is discussed by Professor Frank Adams (*Journ. Geol*, xx, p. 97, 1912). By means of experiments he has come to the conclusions that at ordinary temperatures, but under the conditions of hydrostatic pressure or cubic compression which exist within the earth's crust, granite will sustain a load of nearly 100 tons to the square inch; that under the conditions of pressure and temperature believed to obtain within the earth's crust, empty cavities may exist in granite to a depth of at least eleven miles; and that mineral veins and deposits may thus be formed to as great a depth. To the same Journal (p. 119) Mr. L. V. King contributes an article "On the Limiting Strength of Rocks under conditions of stress existing in the Earth's interior". His experiments show that no state of shearing stress in the crust of the earth, due to the weights of continents and mountains, can cause the collapse of the rock in the neighbourhood of a small cavity. It is also shown that as far as hydrostatic pressure in the earth's crust is concerned, a small cavity at ordinary temperatures will remain open, provided the depth does not exceed a value between 17·2 and 20·9 miles.

VI.—Canadian Clay and Shale Deposits.—A memoir on *The Clay and Shale Deposits of Nova Scotia and portions of New Brunswick*, by Mr. Heinrich Ries, assisted by Mr. Joseph Keele, has been issued

by the Department of Mines, Canada (No. 16E, 1911). In Nova Scotia the Pre-Cambrian, Silurian, Devonian, and Triassic formations yield no materials of great value to the clay-worker, but a short account is given of a felsite quarry in the Pre-Cambrian, the material being locally called 'fire-clay'. From this rock, when crushed and mixed with clay, hard bricks can be manufactured. The important clay-bearing formations are the Lower Carboniferous, Coal-measures and Pleistocene, and some clays that may be of Cretaceous age. In New Brunswick the clay-bearing formations include Lower Carboniferous, Coal-measures, Permian, and Pleistocene. The various clay-works in both provinces are described, with notes of methods of testing the bricks. The concluding portion of the memoir contains a general account of the origin and properties of clay. Numerous illustrations of strata and brick-works are given.

VII.—Were there Climatic Zones in Devonian Time? By G. F. Matthew, D.Sc., LL.D. Trans. Roy. Soc. Canada, ser. III, vol. v, sect. iv, p. 125.

THE views of the Marquis de Saporta and other naturalists who have dealt with early climates of the earth, that there was an entire uniformity of climate in the Carboniferous and preceding ages, is controverted in this paper. The writer agrees with Naumayr and others that there was considerable diversity in these ancient climates. He sets forth the view that the Devonian plants which we know best are those of a northern range of basins. The genera *Cyclopteris* (*Archæopteris*) and *Lepidodendron* (with small areoles) are characteristic of this horizon, and are found both in Europe and America. Several areas where these plants are known are the hill region of Western New York and Northern Pennsylvania, the region of Gaspe, and the Restigondu. Areas in Europe belonging to this northern range are the Devonian of Great Britain and of Belgium, and the Upper Devonian of Bear Island in the Arctic Sea. These are contrasted with the southern range which is developed in the south-eastern part of Canada; the floras here differ from those of the northern range, and more nearly resemble those of the 'Culm' and the Coal-measures. Three principal groupings of plants are recognized in the Upper Devonian beds of this southern district; they are that of the Perry Beds, which have always been regarded as Devonian, that of Kenebecasis and Horton, which Sir William Dawson called Lower Coal-measures, and those of Riverside, etc., in Nova Scotia and Quáco in New Brunswick, which are more like the plants of the Coal-measures.

VIII.—Proceedings of the United States National Museum.

Variscite found crystallized in nodules and in irregular masses of brecciated chert near Lucin, Utah, has been examined in detail by Dr. Waldemar T. Schaller, who presents some interesting results in No. 1867 of the Proceedings (vol. xli, pp. 413–30, pl. xxxiii). Aggregates of deep-green tabular orthorhombic crystals occur, some measuring a millimetre in length. Upon heating the crystals change in colour to lavender, and their pleochroism, which before was weak,

becomes very pronounced and striking. The optical properties of this mineral show some relationship to scorodite, strengite, and phosphorite. Its crystallography and chemical composition are also discussed, and a typical nodule and a crystalline aggregate, with tabular crystals, are figured on the plate.

Camptosaurus.—No. 1878 of the same volume (pp. 687–96, with plates lv–lxi) contains the description of two unusually perfect skeletons, the types of *Camptosaurus nanus*, Marsh, and *C. browni*, Gilmore, that have been mounted for exhibition in the United States National Museum. The specimens formed part of the Marsh Collection and were obtained from the well-known "Quarry 13", near Como Bluff, Albany County, Wyoming. Both stand on a base of artificial matrix representing the sandstone in which they were found, the larger (*C. browni*) being in quadrupedal position, the smaller (*C. nanus*) in bipedal pose and representing a rapidly walking animal with head thrown forward, the right leg at the end of a forward stride, and tail doubly curved and slightly lifted. Some correction of Marsh's earlier restoration has been made, and in the case of *C. browni* a better-balanced animal has been produced by the shortening of the presacral region. The mounting represents nearly the whole length of the toes (except the first) as touching the ground, on account of the fact that certain footprints show nearly the full length of the phalanges. The position in which the bones of *C. browni* were found is shown in a map, and there are also six plates reproducing photographs of the mounted skeletons.

IX.—Petrographic Methods. By Professor Dr. Ernst Weinschenk; rendered into English by R. W. Clark. 8vo; pp. xvii + 396. New York and London: McGraw-Hill Book Company, 1912. Price 15*s*.

THE title *Petrographic Methods* includes the translation into English of two books, *Die Anleitung zum Gebrauch des Polarisationsmikroskops* and *Die Gesteinsbildenden Mineralien*. The first, on the polarizing microscope, appeared in the third edition in 1910, and the second, on the rock-forming minerals, in the second edition in 1907. Both books were then revised, and the work before us is therefore of considerable value to English students of petrology.

The necessity of a thorough knowledge of the fundamental principles of microscopic optical methods in petrology is fully realized in the first part of this book. The discussions on lenses and on polarized light are very clear, and several polarizing microscopes (chiefly by German and American makers) are described. Methods of adjustment and investigations in ordinary and in polarized light are fully dealt with. The use of accessory devices (rotation, heating, and projection) for special investigation is considered in a less detailed manner in the appendix.

In the second part 139 pages are devoted to the description of 106 rock-forming minerals; and preceding these are useful accounts of chemical and physical methods employed in separation and

investigation. Eighteen tables of results at the end of this part complete this volume, which should be of great value for practical detailed work in the laboratory.

X.—Flowing Wells of Central Australia.—In an article on this subject (*Geograph. Journ.*, July and August, 1911), Professor J. W. Gregory further discusses the problem of the origin of the great underground supply of water which occurs in large part of Queensland, the north-western part of New South Wales, and the north-eastern corner of South Australia, and comes to the surface under great pressure when boreholes are put down. He argues that the flowing wells are not artesian in the ordinary sense, but are due largely to plutonic magmatic water deep-seated in origin, and brought to the surface by rock-pressure and gas-pressure produced by the heat of the water. Professor Gregory points out that there is no evidence of sufficient surface areas of intake to account for the great body of underground water from rainfall; moreover, the irregularities in the levels to which the waters rise, their periodic oscillation at non-lunar periods, the varying distribution of the saline ingredients, and high temperatures of some of the wells are pointed out in support of his view. When we consider the fluctuations in level, in temperature, and the varying amounts of saline ingredients in well-waters in Britain, the strongest argument used by Professor Gregory appears to be the inadequate areas for the percolation of rain-water. In any case the wanton waste of water from the flowing wells, to which special attention is directed, should be stopped.

XI.—Glacial Phenomena of Spitzbergen.—Mr. Lamplugh has given an interesting account, to which brief reference was made in the June Number (p. 275), of "The Shelly Moraine of the Sefström Glacier and other Spitzbergen phenomena illustrative of British Glacial conditions" (Proc. Yorks. Geol. Soc., vol. xvii, p. 216, with 13 photographic plates, 1911). While there is evidence of former glaciation over practically the whole of Spitzbergen, the extensive tracts now bare have been so eroded that most of the drifts have been removed. The presence of vast numbers of shells, mostly unbroken, in the terminal moraine of the Sefström glacier, after it had crossed an arm of the sea, shows how readily marine material can be raised from the sea-floor and transported by an advancing sheet of land-ice. The influx of land-ice does not greatly interfere with the state of adjacent land: plants and animals may continue to exist in proximity to the ice-margins. The greatest amount of drift is deposited near the limits reached by the ice. Within less than ten years a mass of Boulder-clay, 100 feet or more in thickness, was piled up by the Sefström glacier. Thickness of drift, therefore, does not necessarily indicate length of time.

XII.—A Palæozoic Fern.—Dr. D. H. Scott has given a full description with illustrations of *Zygopteris Grayi* of Williamson (*Ann. Botany*,

xxvi, p. 39, 1912). He also discusses the structure and affinities of this Carboniferous fern, agreeing with Dr. P. Bertrand that it is a member of the genus *Ankyropteris*.

REPORTS AND PROCEEDINGS.

1.—The Royal Society.

June 27, 1912.—Sir Archibald Geikie, K.C.B., President, in the Chair.

"A Petrified *Williamsonia* from Scotland." By Professor A. C. Seward, F.R.S.

The species *Williamsonia scotica*, which forms the subject of this paper, is founded on a specimen from Upper Jurassic strata, probably Kimeridgian, of Eathie, near Cromarty, in the county of Ross and Cromarty, Scotland, where it was found by Hugh Miller, who published a figure and brief description of it in the *Testimony of the Rocks*. The type-specimen is in the Miller Collection, Royal Scottish Museum, Edinburgh, and it is through the courtesy of the Director that it has been possible to subject the fossil to anatomical investigation. A small piece of the type-specimen is in the Geological Department of the British Museum.

The specimen has the form of an ovate strobilus, 11 cm. long, with numerous linear bracts thickly clothed with long tubular hairs, which form a dense felt between the bracts and between the bracts and the axis of the cone. To the lower part of the peduncle are attached spirally disposed bracts embedded in a packing of hairs. The upper part of the strobilus axis, incomplete at the apex, is invested by a layer, 2 mm. broad, of relatively long and narrow appendages. Of these the great majority are interseminal scales polygonal in section, of almost uniform diameter, and ending distally in a flat truncate apex. Regularly disposed among the scales are slightly narrower and cylindrical megasporophylls, each megasporophyll being the centre of a group of from five to six interseminal scales. The megasporophylls consist of a central column of short parenchymatous cells, corresponding to the seed-peduncles in *Bennettites*, which becomes rather broader in the distal portion or nucellus composed of longer and larger cells. The nucellus of homogeneous structure is closely invested by a single integument, and this envelope overtops the conical apex as a broad micropylar tube with a slightly funnel-shaped free end, in the centre of which is a very narrow micropylar canal.

A comparison is made with *Williamsonia* and *Bennettites*, especially *B. morierei* (Sap. & Mar.), also with strobili described by Wieland as species of *Cycadeoidea*. The question of the systematic position of *Williamsonia scotica* is discussed, and the account concludes with a consideration of resemblances between the Bennettitales on the one hand and Gnetales and Ginkgoales on the other. Allusion is also made to the possible relationship of this dominant Mesozoic group to the Angiosperms.